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BY JOHN A. PORTER, M.A., M.D.,

PROFESSOR OF AGRICULTURAL AND ORGANIC CHEMISTRY IN YALE COLLEGE.

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"We have read this book with great pleasure, and can recommend it as the simplest, most concise, and most comprehensive School Chemistry known to us. Its simplicity is its great merit. It disembarrasses the science of details unsuitable for beginners, states principles plainly and clearly, and by its admirable conciseness is enabled to embrace in a single volume a complete outline of the great modern science, in its organic and inorganic departments."

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"Porter's First Book of Chemistry I have examined with very great satisfaction, and regard it as a most complete, simple, and yet every way admirable compendium of the science for beginners. The larger work I have adopted as a text-book, and I find its logical arrangement and lucid explanations very acceptable to my pupils, and admirably calculated to make them thoroughly acquainted with the important and interesting facts of chemical science. Yours, respectfully,

W. W. HOWARD."

Entered according to Act of Congress, in the year 1856,

By JOHN A. PORTER,

In the Clerk's Office of the District Court for the District of Connecticut.

PREFACE.

IN the preparation of this text-book on Chemistry, it has been the design of the author to disencumber the subject of much detail, which is only of interest to the professional chemist, and at the same time to bring the illustration of the more important phenomena of the science within the reach of every school and every individual student.

The most distinguished philosophers have not deemed it beneath their dignity to employ the simplest means of investigation. The teacher will not be loth to take advantage of similar means in illustrating their discoveries. An important design of this work is to show how this object may be accomplished, by the simple addition of a few test-tubes and a spirit lamp, to a list of chemical apparatus which may be found in every house.

Among the other distinctive features of the work, are a more complete classification than usual according to chemical analogies, the explanation of chemical phenomena in ordinary language, as well as symbols, and the addition of a complete set of formulæ in the Appendix. A number of recent and important discoveries are introduced, and the relations of Chemistry to the Arts and Agriculture, are especially considered.

The method adopted for the explanation of chemical phenomena, while it is believed to be more effectual in imparting the leading idea of all chemical reactions, leaves to the

student the useful exercise of constructing formulæ. He is at the same time supplied in the Appendix with a complete control of his results. This part of the work contains in addition, numerous tables, and other supplementary matter for the use of the more advanced student. The learner should not be required to burden his memory with numbers, expressing atomic weights, specific gravities, &c. It is a barren knowledge. A general survey of the tables, with reference to them for calculations, is sufficient.

The language of the atomic theory has been rigorously adhered to throughout the work, as the best expression of our present knowledge of the constitution of matter. While it is liable to no objection which does not hold against the language of every department of Physics, its uniform employment has the great advantage of accustoming the mind to a conception which furnishes a probable explanation of the most obscure portions of the science.

Several topics introduced in the chapters on Physics, are designed simply as introductory to other subjects, and are very briefly treated, in accordance with this design.

Among the numerous authorities consulted in the preparation of this work, the author would especially mention the works of Berzelius, Liebig, Gmelin, Gregory, Regnault, Payen, Graham, Silliman and Stockhardt. He would also take this opportunity of acknowledging the important aid extended by his able professional assistant, DR. ROBERT A. FISHER, both in the execution of his design for a simplified course of experiment, and for valuable information in relation to several processes of applied chemistry.

Boxes containing APPARATUS and MATERIALS neatly put up to accompany this work, may be ordered of the publishers, A. S. BARNES & Co., 51 and 53 John street, New York. Price \$8.00.

The list embraces all the articles named on the last page of the work, with the exception of those marked with an asterisk, which may be procured of any druggist.

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INTRODUCTION.

ACCORDING to the most ancient view of the constitution of matter, the earth and all material things are but modifications of one and the same original substance. Fire, water, and air, were each in turn asserted to be the primitive element, according to the arbitrary conjecture of philosophers who were bold enough to speculate upon the subject. At a later date, the views of all seemed to be harmonized in ascribing the same dignity to the three contending elements, and including earth among the original varieties of matter. Earth, Air, Fire, and Water, were assumed to be the original materials out of which all forms of matter are produced.

Modern chemistry has dethroned each of these elemental monarchs of the world, and distributed their prerogatives among a larger number. Earth, air, and water, are all excluded from the list of elements, and

fire appears in the modern view as only the transient attendant of chemical combination.

Each one of the acknowledged elements has its own specific properties, affinities, and capacity of combination. These peculiarities, and all resulting phenomena, it is the province of chemistry to investigate and explain. Light, heat, and electricity, stand in intimate relation to all chemical action, either as cause or effect, or unfailing attendant, and are therefore briefly considered in the earlier part of the present work.

The study of science has not for its object the mere gratification of an idle curiosity. Looking at the subject from a material point of view alone, chemistry is one of the great agents in the transformation of nature, and its subjugation to the wants of man. The earth yields her treasure to its skillfully conducted processes, and even the trodden clay becomes converted in its crucible into shining metal. The arts draw from it, with every succeeding year, increased advantage, and the condition of mankind is elevated, and the world advanced by its progressive triumphs. Agriculture also is indebted to its discoveries. It opens to us mines of agricultural wealth in what would otherwise have passed for worthless refuse. It clothes exhausted fields with new fertility, by the addition of some failing constituent whose absence its subtle processes have detected. It carefully investigates the laws and condi-

tions of vegetable growth, by which earth and air are converted into food for man and beast, and thus places us on the highway of sure and rapid improvement.

These practical results, which are the basis of that material prosperity in which taste, and literature, and the graces of life find their natural growth, are by no means to be disregarded. But this is not all. The study of chemical science reveals to the mind a beauty and harmony in the material world, to which the uninstructed eye is blind. It shows us all of the kingdoms of nature contributing to the growth of the tiniest plant, and feeding the germ, as it were, by the inter-revolution of their separate spheres. It shows us how through fire, or analogous decay, all forms of life are returned again to the kingdoms of nature, from which they were derived. Without encroaching upon the domains of the astronomer, it reveals to us still more wonderful relations of distant orbs, which affect not only the outward sense, but supply the very forces which we employ in our contest with the powers of nature. It unveils to us a thousand mysteries of cloud and rain, of frost and dew, of growth and decay, and unfolds the operation of those silent yet irresistible forces which are the life of the world we inhabit.

But the study of nature is worthy of being pursued with a still nobler aim. The glory of the Deity shines in every crystal and blooms in every flower. Every

atom is instinct with a life which the Creator has imparted. The laws that govern minutest particles, as well as the grander revolutions of the heavenly spheres, are but the expression of His will. The reverent study of nature is therefore a contemplation of Deity. Vague and unsatisfactory without the aid of another, and written revelation, it unfolds to the mind thus enlightened, new and exalting evidences of the infinite wisdom and beneficence of the Creator of the world.

INTRODUCTORY.

What does Chemistry tell us of Earth, Air, Fire, and Water?

1. THE Science of Chemistry is of the widest range. AIR, EARTH, FIRE, and WATER, all belong to its domain.

It informs us of the composition of the rocks which make up the mass of the Earth, and of the soil which forms its surface. It tells us of what Air is made, and how it supplies the wants of animal and vegetable life. It separates Water into gases, and reproduces it again by uniting them. It informs us of the nature of Fire, and of the changes which take place in combustion.

What of metals, plants, and wines?

2. It tells us of what plants are formed, and what becomes of them when they decay and disappear. It tells us how to produce metals from ores, wines from fruit, liquors from grain, and shows us the changes which take place in the formation of all these substances. Almost all transformations which occur in the materials around us, as, for example, of iron into rust, of wood or coal into gas, of food into flesh, it belongs to Chemistry to describe and explain.

*Why does it
treat of at-
oms?*

3. As all of these changes result from the action of the minute particles of matter on each other, it is necessary first to consider the subject of Atoms.

*Why of heat
and light?*

4. As the most of them depend on changes of temperature, it is necessary in the first part of the work to consider the laws and effects of Heat. As these laws are best understood from their analogy to the laws of Light, and as Light has an important influence in many chemical processes, a brief chapter on Light precedes the chapter on Heat and its various effects.

*Why is elec-
tricity intro-
duced?*

5. As many, and perhaps all chemical changes, are accompanied by electrical phenomena, it is also important to dwell briefly on the subject of Electricity before proceeding to what is more strictly the science of Chemistry. The first part of this work is, therefore, devoted to the consideration of these subjects; or, in other words, to the Science of Physics.

PART I.—PHYSICS.

CHAPTER I.

ATOMS AND ATTRACTION.

Of what is matter composed? What is said of atoms?

1. **ATOMS.**—All matter is supposed to be composed of exceedingly minute spherical or spheroidal particles, which are held together by their mutual attraction, and are never themselves subdivided. These particles are commonly called atoms. There is reason to believe that the atoms of different substances differ from each other in weight and perhaps in size. The belief that they are never subdivided is not based on their extreme minuteness, but on other grounds, to be mentioned hereafter.

How is the minuteness of atoms shown?

2. **MINUTENESS OF ATOMS.**—Their minuteness is shown by the fact that a single grain of musk will fill a room with its fragrant particles for years, without suffering any considerable loss of weight. The number of atoms it gives off during that time is beyond computation.

Define and illustrate an element.

4. **ELEMENTS.**—There are at least sixty different kinds of matter. Each kind which cannot be separated into other kinds is called an elementary substance, or simply an element. Iron

and carbon or charcoal are elements. Iron rust, on the other hand, is a compound. There are, of course, as many different kinds of atoms as there are of elements.

What is Cohesion? Illustrate the subject.

5. COHESION.—The force which binds together atoms of the same kind is called the attraction of cohesion, or simply cohesion. In the more tenacious substances,

such as iron or copper, the force of cohesion is immense. The strength of a horse is insufficient, for example, to break an iron wire one-fourth of an inch in thickness. It is because in every section of the wire the atoms attract each other with a superior force. And, as we may imagine innumerable sections in every inch of the wire, we see that there is in every inch a force of attraction exerted, which in its sum total is inconceivably great. Attraction between unlike atoms in contact with each other, as between glue and the wood to which it is applied, is called adhesion.

How does Gravitation act?

6. GRAVITATION.—Unlike the force of attraction mentioned in the preceding paragraph, gravitation acts at all distances. It

is the reason of the weight of bodies, one body weighing twice or three times as much as another, because it has twice or three times the quantity of matter to attract and be attracted by the earth.

What is Chemical Attraction or Affinity?

7. CHEMICAL ATTRACTION OR AFFINITY. The force which unites unlike atoms into compounds possessing new properties is called *chemical attraction* or *affinity*. Thus

iron and oxygen unite by chemical attraction to form iron rust, a substance different from either. The

and act at a small distance. Attraction of adhesion, and affinity, act at a small distance.

gas chlorine and the metal sodium unite, as will be hereafter seen, to form common salt. When substances become thus united by chemical affinity, the resulting compound is not a mere mixture, with properties of both constituents, as when salt and sugar are mixed, it is, on the contrary, a new substance with properties of its own.

Do the forces of Cohesion and Chemical Affinity act at great distances?

8. DISTANCE OF ATTRACTION.—The forces of attraction above mentioned, with the exception of gravitation, act only at immeasurably small distances. Two plates of glass an inch apart do not attract each other; even when brought into absolute contact they do not adhere. But if powerfully pressed, the atoms are brought within the range of the force of cohesion, and cannot again be separated. So iron and oxygen will not attract each other from a distance, but when brought together, unite in consequence of their chemical attraction.

Illustrate the three different kinds of Attraction.

9. The three kinds of attraction are perfectly illustrated in a falling drop of water. Affinity holds together the atoms of oxygen and hydrogen which make up each particle of water. Cohesion unites the particles of water thus formed, to make the drop, and gravitation causes the coherent drop to fall.

What are the three states of matter?

10. THREE STATES OF MATTER.—There are three distinct states or conditions of matter—the solid, the liquid, and the gaseous. Almost all substances may be made to assume each of these states. Thus, a piece of solid sulphur, if heated up to a certain point, melts and becomes

liquid. If the liquid sulphur be exposed to a still higher temperature, it passes off in the form of a vapor or gas.

11. CONTACT OF ATOMS.—The atoms

Are atoms in contact?

What is the cause of the difference of cohesion in bodies?

of matter are not supposed to be in absolute contact in either solids, liquids, or gases. This is inferred from the fact that all substances may be diminished in bulk by pressure. But in solid bodies the attraction of cohesion between the atoms is strongest, and they are more nearly and firmly bound together. In liquids, cohesion is less than in solids, and the atoms are farther separated. In gases, cohesion is entirely overcome, and but for gravity, the atoms would separate themselves indefinitely.

Heat is the main cause of this difference in cohesion. This subject will be more fully considered in the chapter on Heat or Caloric.*

* The subject of Crystallization belongs to Physics, and in a strictly scientific arrangement, would be considered in this place. The student will find the most accessible illustrations of this subject in the Salts, which are considered later in the work, and it has therefore been introduced in the chapter which treats of these compounds. It is to be borne in mind that what is there said of crystallization, relates to other compounds and to elementary substances, as well as to salts.

CHAPTER II.

LIGHT.*

In what cases does light act chemically? 12. CHEMICAL ACTION OF LIGHT.—Daguerreotype pictures are produced by the chemical action of light. So light acts chemically in converting water and the carbonic acid of the air into vegetable matter. The action of light in these cases will be explained hereafter. The present chapter is devoted to the consideration of its nature and more important laws.

Has light weight? 13. LIGHT IS WITHOUT WEIGHT.—While the effects of light, and the laws according to which they take place are well understood, philosophers differ with respect to its nature. It is, however, agreed that light is imponderable, or without weight, this being inferred from the fact that an illuminated object weighs no more than the same object when unilluminated.

What is Newton's theory? How is the sensation of sight produced? 14. NEWTON'S THEORY.—Newton maintained that light is a fluid thinner or more subtle than air, or any gas, but composed like these of minute particles, constantly given off from the sun and all luminous objects. He supposed that it is this substance passing into the eye that produces the sensation of sight, as the fine particles of fragrant matter, passing off from flowers, produces the sensation of smell.

* This chapter is designed solely as an introduction to the subject of Heat. The undulatory theory is therefore not particularly considered.

15. UNDULATORY THEORY.—Another

What is the other view of the nature of light?

view is that the fluid above described does not pass from the sun and other luminous objects to the eye, but fills the space between them and serves as a medium for producing the sensation of light, as the air does for producing sound.

Illustrate this view?

16. When a bell is struck its vibrations are communicated to the air, and so to the ear, producing the effect of sound. So, according to the view of light last mentioned, vibrations are caused by some means in the sun and certain other bodies, which being rapidly transmitted through the fluid above mentioned, produce, when they fall on the eye, the sensation of light.

How is this fluid known to exist?

17. EXISTENCE OF THE SUPPOSED FLUID. Such a fluid as this theory requires is known to exist in the spaces between the heavenly bodies, by the influence which it exerts on their motions, and is supposed to pervade all substances, whether solid, liquid or gaseous, occupying the spaces between their particles. It is called *ether*, but has no relation to the chemical and medicinal liquid of the same name.

How does either view explain reflection?

18. For the explanation of the leading phenomena of light, it matters little which of the views above mentioned is adopted.

Thus, it is certainly true that light is reflected from mirrors, whether we suppose it a subtle fluid, and that its reflection is the glancing off of its particles from the polished surface, (as a ball thrown obliquely against the side of a house glances off from

it,) or whether we suppose it to consist of vibrations, which are made to glance off as the vibrations of the air in the case of echoes.

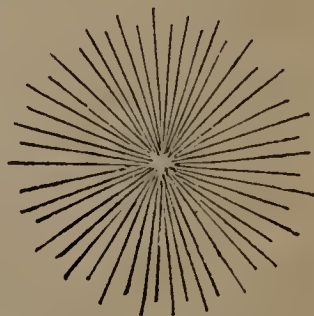
What is the advantage of the Newtonian theory? 19. The first, or Newtonian theory, enables us to explain the leading facts more simply and clearly, and is therefore employed in this work for this purpose. The definitions and laws of light are stated in the language of that theory.

What is a ray of light? Illustrate the subject. 20. RAY AND MEDIUM DEFINED.—A ray of light is a line of particles of light. In such rays or lines of particles, light is constantly passing off from all visible objects. From every part of the book before the student, for example, it passes into the eye, enabling him to know the nature of the object. If the book is taken into a dark room it is no longer visible, because it obtains no light which it may afterward reflect to the eye.

What is a medium? A medium is any space or substance through which light passes.

Give the laws of light? 21. LAWS OF LIGHT.—The more important laws of the radiation of light are the following :

1. Rays of light proceed from every point of luminous objects in every direction. They proceed, for example, from every point of the sun's surface

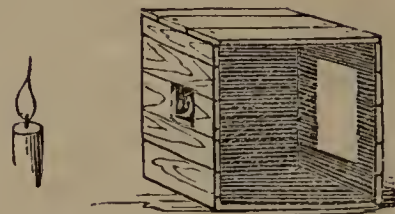


2. They proceed in straight lines. Light, for example, comes to us in straight lines from the sun.

3. They diverge as they proceed. This is illustrated

in the figure, the central point being supposed to be a star or other source of light.

Explain the divergence of rays of light. 22. DIVERGENCE OF LIGHT.—By the divergence of rays of light



is meant that they spread themselves over more space, the further they proceed from their source. This is illustrated in the figure, where the light of a candle is represented as passing through a window, and illumining a larger space on the opposite wall.

Give the law of divergence, and illustrations. 23. LAW OF DIVERGENCE.—When the distance is doubled, the surface that light will cover is quadrupled. This is also illustrated in the figure. The wall being twice as far from the candle as the window, the light covers four times the surface. If the distance of the wall were three times that of the window, the surface covered would be nine times as large as the window; if four times, the surface covered would be sixteen times as large. It is evident from these figures that the surfaces covered, increase as the squares of the distances. The light, of course, diminishes in intensity in the same proportion, as it is thus spread over greater surface. At four times the distance, it has only one-sixteenth the intensity, and so on.

Explain the reflection of light. 24. REFLECTION OF LIGHT.—If a ball of ivory or other material is thrown perpendicularly against any hard plane surface, it will return in the same line; if it is thrown obliquely,

it will glance off with the same degree of obliqueness in the other direction. Light is reflected from plane surfaces in the same manner.

This reflection is illustrated in the figure, which represents a mirror, and a ray of light falling upon it and again reflected.



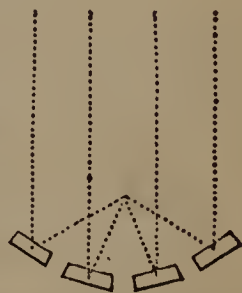
Explain the change of apparent place by reflection.

25. APPARENT PLACE CHANGED BY REFLECTION.—As we always seem to see an object in the direction from which its rays enter the eye, a mirror which changes the direction of the rays will change the apparent place of the object. Thus, if the rays of the sun fall obliquely upon a mirror, and are reflected to the eye, we shall seem to see the sun in the mirror, in the direction which the rays have acquired after reflection.

Why do concave mirrors converge rays of light?

26. CONCAVE MIRRORS.—On considering that rays are reflected from plane surfaces with the same degree of ob-

liquity with which they fall upon them, we shall be able to comprehend how it is that concave mirrors have the property of converging rays of light, or bringing them together in a point.

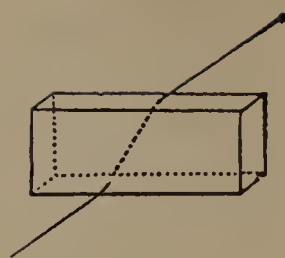


A number of small plane mirrors, situated obliquely toward each other, as represented in the figure, and as they might be arranged in a bowl or saucer, would evidently have this effect. As a concave mirror may be regarded as made up of innumerable plane mirrors, similarly arranged, it would obviously be productive of the same effect.

27. REFRACTION.—Re-

What is Refraction?

fraction is the change of direction which a ray experiences in passing obliquely from a rarer into a denser medium, or the reverse.



Explain the figure.

28. The figure represents a block of glass, and shows the direction which a ray of light would take on entering and emerging from it. On entering, it makes a bend, and passes on through the glass less obliquely; that is, more nearly in the direction of a line drawn perpendicularly to the surface of the glass, and continued through it. On passing out again it would be bent away from such an imaginary perpendicular line, and re-assume its previous course.

Give another statement of the laws of Refraction.

29. ANOTHER STATEMENT OF THE LAW.—

As the perpendicular has only an imaginary existence, it is perhaps easier to fix in the mind the changes of direction of rays passing in and out at regular surfaces thus: A ray, on entering a denser medium pursues within it a course further from the nearest portion of the surface than its original course would be if continued. And a ray entering a rarer medium takes a course nearer the nearest portion of the surface than its original course would be if continued. These statements are true for all plane or uniformly curved surfaces.

30. ILLUSTRATION.—A

Illustrate by a coin.

coin placed in a tea-cup, as represented in the figure, so as to be barely concealed from the eye, will be rendered visible by filling the cup with water.

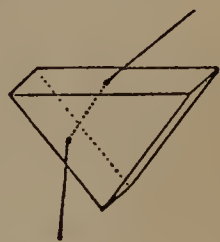


The surface of the water furnishes a point of transition from a denser to a rarer medium, and the direction of the ray is thereby changed in accordance with the law above stated. It is thereby enabled to turn a corner, as it were, and come to the eye.

What effect has a prism on a ray of light?

31. TRIANGULAR PRISM.—Bearing the rules last given in mind, it will be readily seen that the course of a ray of light pass-

ing through a prism must be such as is represented in the figure. The ray may be supposed to start from below or above the prism. The line of its passage through the glass will be the same in either case.



Illustrate the effect.

32. Let us suppose it to pass upward from a bit of white paper or other object to the eye of an observer above. The appa-

rent place of the object will be changed. It will be seen still beneath the prism, not where it actually is, but in the direction in which the ray points as it enters the eye. This experiment may be made equally well with the water prism described in the next paragraph.

How may a prism be constructed?

33. CONSTRUCTION OF A PRISM.

The prism commonly used in optical experiments is of solid

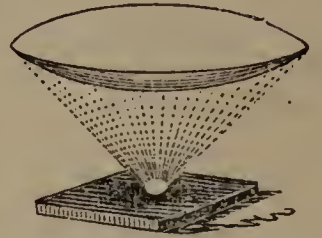
glass. In lack of this, its place may be readily supplied by the water prism represented in the figure. A strip of window glass is to be scratched with a file and broken into three pieces of equal length. These are set up, as represented in the figure, upon another bit of glass previously warmed and thickly covered with sealing wax. When the wax is cooled, and the bits



of glass which it holds will stand alone, the corners where they meet are also closed with sealing wax. The prism is then filled with water, taking care not to moisten the upper edges, and a glass top is afterward attached by wax.

Explain the action of the convex lens. 34. ACTION OF THE LENS. — The property which a convex lens possesses of converging rays

of light and heat, and bringing them together in a point, is also a consequence of refraction. All of the rays which fall upon its surface are bent, as shown in the case of the prism ; but, owing to its shape, they are bent in different degrees and directions, so that they all meet in a point. This point is intensely bright if brought on a dark object, and is called the focus.



Explain another law of refraction. 35. There is another law of refraction thus far left out of view, which is essential to a full understanding of the convex lens. According to this law, the more obliquely a ray falls upon any surface the more it is refracted or bent out of its course. And it is a consequence of the shape of the lens, and its greater steepness toward the edge, that of all the parallel rays which fall upon its surface, those which fall furthest from the center fall most obliquely, and enter the air again more obliquely. In proportion, therefore, as they need to be bent to be brought to the focus, they are thus bent by the action of the lens.

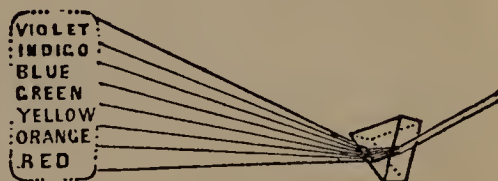
How is light composed? 36. ANALYSIS OF LIGHT.—It has, up to this point, been assumed that light is sim-

ple in its nature, but it may be proved by experiment that every beam of white light such as we receive from the sun is made up of rays of different colors.

How is its composition proved? 37. This may be done by holding a prism in the sun and allowing the light

to pass through it and fall upon an opposite wall or

screen. A beautiful parti-colored spot will be produced, called the solar spectrum. The beam of light which enters the prism is separated by it into rays of seven different colors. The experiment, if performed in a dark room, into which light is admitted through a very small opening, is extremely beautiful.



How does refraction decompose light?

38. The rays, before entering the prism, passing along together parallel with each other, form white light; but on entering the glass and emerging from it, each of them is refracted or bent out of its course in a different degree, and they are thus separated, and made to appear with their own colors. Why one ray is refracted more than another is not known. The above experiment proves it to be a fact, and this is all our knowledge on the subject.

Do lenses decompose light?

39. LENSES DECOMPOSE WHITE LIGHT AND RECOMBINE THE RAYS.—This separation of white light into colored rays occurs always when light passes through a prism; but, for the sake of simplicity, this fact was left out of consideration in paragraph 29, the object in that place being simply to show the general direction of the light as it passes

through the prism. Such separation also occurs when light passes through a lens, but the different colored rays on emerging again from different points of the lens overlap each other, and are in great part united again to form white light.

CHAPTER III.

HEAT.

Section 1.—Nature and Sources of Heat.

Has heat weight? Give an illustration 40. NATURE OF HEAT.—It was remarked in the commencement of the chapter on light, that philosophers, although acquainted with its facts and laws, differed in opinion as to its nature. The same is true of heat. It is agreed, however, that heat, like light, is imponderable, or without appreciable weight; this being known from the fact that a heated body weighs no more than a cold one.

41. If the end of a bar of iron is heated, the other end soon becomes hot. There is no doubt as to the effect, and it would seem that something must have passed from the fire, along through the rod to produce it. But we do not certainly know that any substance has been thus transmitted. It may be that heat is analogous to sound, and produced by vibrations. Being thus in doubt, we say that the nature of heat is not understood.

State the mechanical theory. 42. MECHANICAL THEORY.—One view is that a very subtle fluid coming from the fire has actually passed along through the mass of metal, and from that into the hand, and so caused the sensation of warmth or heat. And this supposed substance is called heat, or caloric.

What is the theory of vibration?

43. THEORY OF VIBRATION.—Another view, corresponding to the second view of light, is, that heat is not a fluid, but, like light, the result of vibration in the ether which is every where present. The vibrations which produce the sensation of heat are, of course, different from those which produce that of light, as the movements of the air which produce heavy and sharp sounds are different. We must suppose, indeed, in the former case, that a much greater difference exists. But it is assumed that both are the result of vibrations of some kind.

Give the illustration.

44. ILLUSTRATION.—When a bell is struck its vibrations are communicated to the air, and so to the ear, producing the effect of sound. So, according to this view, vibrations of a peculiar kind are caused by some means in the sun, and all sources of heat, and, being rapidly transmitted through the ether, produce, when they fall upon our bodies, the sensation of heat. The bar heated at one end becomes hot at the other, because certain vibrations, originated in the fire, are gradually transmitted through the ether, and the iron which it pervades, to the other end.

What is the limit of our knowledge of the subject?

45. THE FACTS ARE DEFINITELY KNOWN. It may seem strange to the reader that there should be this doubt in relation to so common a subject as heat. But there is a similar limit to our knowledge in most of the sciences. In physiology, for example, we know that muscle, and bone, and other parts of the body, are produced from the blood, and that life, or vital force, is essential to

their production ; but how the vital force operates we do not know. But, as in physiology this ignorance does not prevent us from comprehending the structure of the human body and the uses of its different organs, so ignorance in relation to the nature of heat does not interfere with the acquisition of the most perfect knowledge of its effects, and the laws according to which they happen.

What theory is adopted in this work ? Explain it. 46. THE MECHANICAL THEORY HERE ADOPTED.—In the present volume the former of the views which have been mentioned is adopted, and heat, like light, is assumed to be an exceedingly subtle imponderable fluid.

To return to the example of the heated bar, it grows hot at the end farthest from the fire because the fluid actually passes through its solid substance, and is so communicated to the hand.

What is meant by the term cold ? 47. DEFINITION OF COLD.—Cold is a relative term signifying the comparative absence of heat. But the coldest bodies which we know of, as ice, for example, contain heat, and may be made colder by its withdrawal.

State the principal sources of heat. 48. SOURCES OF HEAT.—The principal sources of heat are the sun and fixed stars, chemical action, electricity, and friction. It is by no means certain that these should be distinguished as different sources ; for the heat of the sun may be due to chemical action, and electricity is, as we know, excited both by chemical action, and by friction.

How much heat does the sun send to the earth?

49. QUANTITY OF HEAT THE SUN SENDS TO THE EARTH.—The sun sends enough heat to the earth every year to melt a shell of ice enveloping the earth a hundred feet thick. This may be ascertained by observing what thickness the average heat of the sun will melt per minute, and then calculating the quantity for a year. The method actually pursued is slightly different from this, but the same in principle. The sun, in fact, sends a larger amount of heat to the earth than is above stated, but 40 per cent. of it is absorbed by the atmosphere. The quantity above given is the remaining 60 per cent.

How much heat is given out by the sun and its atmosphere?

50. TOTAL QUANTITY OF HEAT THE SUN GIVES OUT.—Knowing how much comes to the earth and its atmosphere, it is easy to calculate how much starts from the sun. It is just in proportion to the extent of the whole visible heavens, as seen from the sun, compared to the space occupied by the earth, as seen from the same point. By making the calculation it is ascertained that a quantity of heat is given out from the sun in a year which, if it all came to the earth, would melt a crust of ice nearly 4000 miles thick, or a quantity which would melt every minute a crust nearly thirty-seven feet in thickness. But the heat of a blast-furnace, if kept up constantly to the highest point, would melt but a little over the thickness of five feet of ice per minute. The sun's surface is, therefore, more than seven times as hot as the glowing surface of the fire of a blast-furnace.

*What is said
of the heat of
fixed stars?*

51. HEAT OF THE FIXED STARS.—The fixed stars are suns of other systems, and sources of heat, like our own sun. And their number is so great, that notwithstanding their distance, they exert a very important effect on the temperature of the earth. It is estimated that they give us four-fifths as much heat as the sun, and that without this addition to the sun's heat, neither animal nor vegetable life could exist upon the earth.

*Give examples
of heat pro-
duced by che-
mical action
and by electri-
city.*

52. HEAT OF CHEMICAL ACTION AND ELECTRICITY.—We shall see hereafter that heat is evolved in almost all cases of chemical action. Indeed, the heat of our fires has this origin, as will be explained in another chapter. The heat of lightning is developed by electricity.

*Give examples
of heat pro-
duced by fric-
tion.*

53. HEAT FROM FRICTION.—The heat produced by slight rubbing is sufficient to set on fire a phosphorus match. Sir Humphrey Davy produced heat by friction between two pieces of ice. It is said that Indians produce fire by rubbing two sticks of wood together. Count Rumford caused water to boil by boring a cannon beneath its surface. These are all cases of the production of heat by friction.

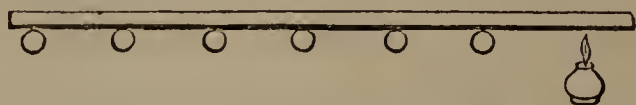
Section 2.—Communication of Heat.

54. Heat is communicated by conduction, convection, and radiation. These three modes of communication will be considered in the order in which they are named.

CONDUCTION.

Explain the conduction of heat.

55. Conduction is the passage of heat through a body by communication from particle to particle. An iron wire, one end of which is held



in a flame, soon grows

hotter at the other, by conduction of the heat of the flame. The progress of heat along a wire may be shown by fastening marbles to it with wax, as represented in the figure, and then heating one end by a lamp. The marbles drop off successively, as the heat in its progress melts one bit of wax after the other. The communication of heat from one body to another in contact with it is also a case of conduction.

When does conduction cease?

56. WHEN CONDUCTION CEASES.—Conduction proceeds toward the cooler portions of a body until all its particles become equally hot, just as the absorption of water by a sponge continues until all its pores are filled. This point being reached, there is no tendency to further motion within the heated body.

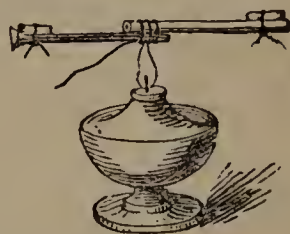
What substances are the best conductors?

57. THE METALS ARE THE BEST CONDUCTORS.—The earths and wood conduct very slowly; fine fibrous substances, like

wool, cotton, fur, and feathers, slowest of all. Liquids and gases, as will be hereafter seen, are non-conductors of heat. The superior conducting power of metals is shown in the rapidity with which an iron wire, one end of which is held in the flame of a lamp, grows hot at the other end. A splinter of wood, or a pipe-stem, is heated from end to end much less rapidly, while scarcely any heat would be communicated along a roll of cotton cloth, one end of which was inflamed.

*How may the
conducting
power of met-
als, &c. be il-
lustrated?*

58. ILLUSTRATION.—The difference of conducting power in metals and earths may be illustrated by fastening



together by a wire, as represented in the figure, an iron nail and a bit of pipe-stem of equal length, and heating them over a spirit lamp. The end of a match having been fastened with thread to each, it is found that the heat will travel along the nail and inflame the match at its end long before the other match is ignited.

*How are we
protected from
the central heat
of the earth?*

59. PROTECTION FROM THE CENTRAL FIRE OF THE EARTH.—We are protected from the central heat of the earth by the non-conducting power of the rocks and soil which

form its outer crust. So a crust forms after a time over the streams of lava which flow from volcanoes; but, owing to its non-conducting power, the lava below remains liquid for years.

*When does con-
duction take
place most ra-
pidly?*

60. CONDUCTION FROM ONE BODY TO ANOTHER.—This takes place most rapidly the more perfect the contact between the two. Conduction from air or a gas to a

solid is slow, because the gas contains comparatively few atoms, and therefore furnishes few points of contact. Between a liquid and a solid it is more rapid, because there are more. A cannon ball would grow hot much more rapidly in boiling water than in air of the same temperature. Between solid and solid, again, conduction is less rapid, because the surfaces cannot adapt themselves to each other, like liquid and solid, so as to bring all their atoms together. This paragraph refers solely to the passage of heat from the atoms of one surface into those of the other. The further conduction of heat depends on the substance into which it has passed.

Why is water heated sooner in an iron than in a glass vessel? 61. HEATING WATER.—Water is sooner heated in an iron pot, or other metallic vessel, than in one of porcelain, glass, or earthen-ware, because the metal conducts the heat through from the fire more rapidly. Cooling, or the passage of heat outward when the vessel is removed from the fire, goes on more rapidly in the case of the metallic vessel for the same reason. These statements have reference only to vessels which are not polished. In the case of bright surfaces, another principle is involved to be considered hereafter.

Exp'lain the subject of clothing and its relation to heat. 62. CLOTHING.—Fibrous substances, like wool, cotton, and furs, are best adapted for clothing because they are such poor conductors, and beside, because they contain air shut in between their fibres, which is a non-conductor, as will be hereafter shown. The object of clothing is not to impart heat, but to prevent its escape

from the body. It escapes more or less through all substances, but less rapidly through the fibrous materials just mentioned, and therefore their superiority for winter clothing. If we lived in an atmosphere hotter than our bodies, the object of clothing would be to exclude heat, and the same non-conducting materials now used would be best adapted for this purpose also. Sometimes it is actually the object of clothing to keep out heat ; as, when workmen enter hot furnaces in certain manufacturing processes. Thick clothing, of non-conducting materials, is obviously best in this case also. In summer, coarser fibre of linen, which is a better conductor than cotton or wool, is more used, because it conveys away the heat of the body more rapidly, as is desirable in the warmer season.

Why has the Deity varied the covering of animals? 63. FURS OF ANIMALS.—We see, in what has been stated, the reason why the Deity has clothed animals inhabiting cold climates with fine furs. While the elephant of the torrid zone has but a few straggling hairs, the polar bear has a thick coat of fine fur to keep in his vital heat, and enable him to endure the extreme rigor of a northern climate. So the sea-fowl has a thick covering of soft down to protect him from the cold of the ocean, while the ostrich has an open coat of scanty feathers.

Why does snow tend to keep the earth warm during winter? 64. WARMTH OF SNOW.—Snow keeps the earth warmer in winter than it would otherwise be, not because of any heat it imparts, but because, by reason of its low conducting power, and that of the air which it con-

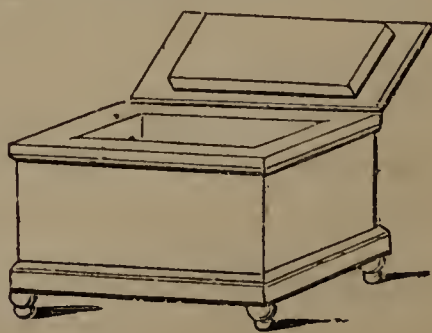
tains, it prevents the escape of the heat which is stored in the earth from the previous summer. But for this protecting influence of the snow, the cold of a single winter would be sufficient to kill whole races of plants. Thus, the cold of the winter weaves a garment to protect the earth from its own influence.

How do the principles of conduction apply in the case of buildings?

65. BUILDING.—In building, the same principles apply as in the case of clothing. Bad conductors, when suitable in other respects, are the best materials for walls, making a house cooler in summer and warmer in winter. Wood and brick, for example, are in this respect better than iron. They keep out the heat in summer, and, though they have the same effect to exclude the heat of the sun's rays in winter, they more than make up for this by preventing the escape of the larger quantity of heat produced by the fires inside. The inhabitants of the Arctic regions build their winter huts of snow, and thus make practical use of its low conducting power. Double doors and windows have more than a double effect in preventing the escape of heat in winter, because of the non-conducting wall of air between them.

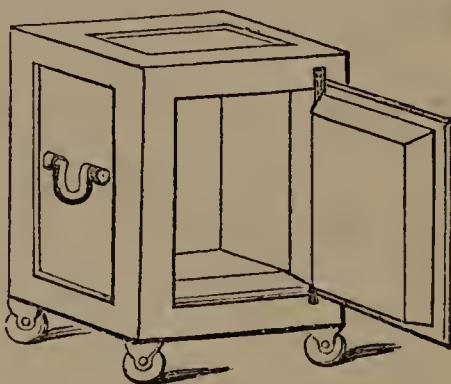
What is the principle involved in the construction of refrigerators?

66. REFRIGERATORS.—These are double-walled wooden boxes, used to preserve articles of food from the heat of the summer. The space between the double walls and top is filled with pulverized charcoal, which has in itself very little conducting



power, and again is non-conducting because of the air between the particles.

67. FIRE-PROOF SAFES.—These are constructed on the same principle, the space between the double walls being filled with gypsum, or some other non-conducting material. They are used as repositories of valuable papers and other property, for greater security in case of fire.



How does conduction influence the sensation of heat?

68. SENSATION OF HEAT.—A metallic door-knob feels colder than the wood to which it is fastened, although it cannot actually be so. It is because the metal is the best conductor, and carries off the heat of the hand more rapidly. If a piece of metal and wood be placed in a hot oven till both become equally hot, as they must by long exposure to the same heat, the metal will feel hotter than the wood. It is because the metal, by its greater conducting power, supplies heat more rapidly to its own surface to be taken away by the hand.

Give a simple test for determining the conducting power of a body.

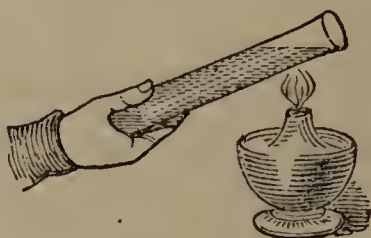
69. SIMPLE TEST OF CONDUCTING POWER. As a general rule, the colder a body feels, the better conductor it is. That this is usually the case is evident from the last paragraph. On applying this test, we find the metallic lamp-stand, cooler, and therefore a better conductor than the table cover on which it stands. In an oven, or other place where the heat is greater than that of our bodies, the inference is reversed. For

the flow of heat would be in this case into the hand, from this highly heated object, and the body that brought it fastest, or felt hottest, would be thereby proved to be the best conductor.

How can it be proved that liquids are non-conductors?

70. LIQUIDS NON-CONDUCTORS.—Water in a test-tube may be boiled at the top while ice frozen into the bottom will remain unmelted. If a

bar of metal with a cavity at the bottom for the ice were heated in the same way, the heat would be conducted downward so rapidly that the ice would soon disappear.



Explain the experiment with ether to prove that liquids are non-conductors of heat.

71. FIRE ON WATER.—Fire may be kindled on water by pouring a little ether upon its surface and inflaming it. But the flame will be found to have slight effect on the



temperature of the water. And, what little effect it has, is principally due to the fact that the glass or metal of the containing vessel carries the heat downward and distributes it to the liquid. When water is heated by a fire beneath it, it is not by conduction, but by another process, explained in a subsequent paragraph. The above experiment may be made in a tin cup very nearly filled with water. A tea-spoonful of ether having been poured on the water, the bottle is to be corked and set away, for fear of explosion, from the kindling of the ether which it contains. The experiment, as described, is not in the least degree dangerous.

CONVECTION.

Explain how liquids become heated.

72. It has been already shown that liquids and gases are non-conductors. This implies that they cannot be heated, like a mass of metal or other solid, by communication of heat from particle to particle. Each particle, on the contrary, receives its heat directly from the source of heat, and conveys it away, making room for others. Hence the term *convection*. In the process of boiling water, for example, the first effect of the fire is to heat the lower layer of liquid, and thereby to expand and make it lighter. It then rises as a cork would in water, and gives place to another portion, which becomes heated and rises in its turn. Thus a circulation is commenced, the warmer portions ascending and the cooler descending, which continues until the water boils. Before this happens, each particle will have made many circuits, accumulating heat with each return, but not communicating it to others. Air and gases become heated in the same way.

How can the circulation produced in liquids by heat be rendered visible?

73. CONVECTION MADE VISIBLE.—The circulation above described may be rendered visible by adding a little of the “flowers of sulphur” to water, and then heating it in a test-tube over a spirit lamp. The suspended particles will be found to move in the direction indicated by the arrows, showing that the water has the same motion. The



upward current is not, it is to be remembered, because of any tendency of heat to rise. Heat, on the contrary, travels in one direction as well as another. But it is, as before explained, because hot water is lighter than cold. Dust of bituminous coal answers the purpose in this experiment still better than "flowers of sulphur." It is necessary to have something that will neither sink or swim, but remain suspended in the water.

How does a room become heated? 74. HEATING ROOMS.—A room becomes heated by a stove in the same manner.

The air in immediate contact with the hot surface becomes heated and rises. Cooler air comes in from all sides to take its place, grows warm, and rises in turn. A circulation is thus established precisely similar to that which occurs in the tube, as represented in the figure. Any light object, as a feather, or a flock of cotton-wool, held over a stove or an open flame, will prove by its ascent the existence of the upward current. A smaller portion of heat is also communicated by direct radiation, and by re-radiation, from the objects which first receive it. In the case of an open fire-place, this is the principal source of heat.

How is the atmosphere heated? 75. CONVECTION IN THE HEATING OF THE ATMOSPHERE.—Heat is distributed through the earth's atmosphere in the same manner.

At the equator, where the surface is hottest, the air heated by contact with it rises and flows off toward the poles, while colder air from the polar regions flows in to take its place, to be heated and rise in turn, continuing the circulation. But for this arrangement, the

equatorial regions, which are constantly receiving excess of heat from the sun, would soon become uninhabitable from its accumulation, and the polar regions, from extreme cold. The currents or winds thus produced are subject to great irregularities, which are considered in works on Natural Philosophy.

RADIATION.

What are the laws of the radiation of heat?

76. The general laws of radiation are the same for heat as for light. Rays of heat diverge constantly from all points of the surface of all bodies, in straight lines and in every direction; and the intensity of heat varies inversely as the square of the distance. The latter point is explained in the chapter on light.

Illustrate the fact that heat is always being radiated from bodies.

77. HEAT IS RADIATED FROM ALL BODIES. It is to be observed that while light proceeds only from certain bodies, heat proceeds from all points of all bodies without exception. If the mercury in a thermometer were frozen by extreme cold, and then hung in a cavity made for the purpose in a block of ice, radiation of heat from the ice would melt it, even if there were no air in the cavity to help melt it by conduction.

What can be said of the proportion of radiation to temperature?

78. PROPORTION OF RADIATION TO TEMPERATURE.—The hotter a stove is the more heat it gives out. This is obvious, and we might naturally suppose that a stove twice as hot as another stove, compared with other objects about it, would give out heat just twice as fast. It

gives out heat, in fact, more than twice as fast, the rapidity of radiation being more than in proportion to the temperature.

What are the effects of rough and polished surfaces on radiation?

79. POLISH IS UNFAVORABLE TO RADIATION.—A coffee-pot of well brightened metal will keep its contents hot much better than a dingy, blackened one, thus rewarding the housewife for her pains. The brightness is not the cause of this effect. It is owing to the increased density of the outer surface which accompanies high polish. For it is satisfactorily proved by experiment, that by adding to the density of a surface, its radiating power is reduced, and *vice versâ*. It is also generally found to be true, in the comparison of different substances, that radiating power is in some degree proportioned to density. Thus, lamp-black, paper, and cotton cloth, have high radiating power; glass, plumbago, and shellac, less; and the metals least of all.

It is to be borne in mind, that it is the *outer surface* exclusively which influences radiation. Thus, a gilded globe of glass, radiates as poorly as solid metal, and the polished coffee-pot, used as a previous example, becomes a good radiator, and cools quickly, if covered over with paper or cotton cloth.

What effect has color on radiation?

80. COLOR DOES NOT AFFECT RADIATION.—A black coat wastes no more of the heat of the body by radiation than a white one. Except in the direct rays of the sun, one is just as warm as the other. But the former absorbs and imparts

to the body more of the heat which comes to it associated with intense light, as is the case with the heat of the sun, and therefore its advantage as an article of winter clothing.

What is said of the transmission of heat through bodies?

81. TRANSMISSION.—The heat of the sun passes through all transparent bodies with but slight diminution. But heat from less intense sources is absorbed, and in large part stopped by many substances which allow light to pass; such are water, and alum, and glass to a less extent. A glass plate held between one's face and the sun will not protect it, but held before the fire will intercept a large part of the heat. So a glass lens or burning-glass will stop the heat of a fire, instead of transmitting and concentrating its rays, as it does those of the sun. It is a singular fact, on the other hand, that many substances which stop the light, transmit heat very perfectly. Such are black glass and smoked quartz crystal. Rock salt allows heat to pass so completely that it has been called the *glass of heat*.

What bodies are the best reflectors of heat? Illustrate the subject.

82. REFLECTION OF HEAT.—Polished metallic surfaces are the best reflectors. Coffee takes longer to boil in a bright coffee-pot, because the heat is reflected from the bright surface and does not enter the liquid. If it were desired to heat a liquid as rapidly as possible, and keep it hot as long as possible in the same vessel, it would be wise to take a dingy one for the rapid heating of the liquid, and then to polish it in order to fasten the heat in. Glass mirrors do not reflect heat so well as those of uncovered metal, because of the absorbing

power of the glass, mentioned in the last paragraph. But this absorbing power is very slight for heat which comes from an intense source like the sun, so that such mirrors reflect the solar heat quite perfectly.

*What bodies
absorb heat
best?*

82. ABSORPTION OF HEAT.—Surfaces are good absorbers, in proportion as they are poor reflectors. All the heat that falls on any surface, must be either reflected or absorbed. In proportion, therefore, as little is reflected much is absorbed.

*What effect
has color on
the warmth of
clothing?*

83. ABSORPTION CONTINUED.—Dark clothing is warmer than that of light color, for the reason, that heat associated with light seems to follow the laws of the latter and undergo absorption or reflection with it. Now we know that dark objects owe their dark color to the fact that they absorb much light, and reflect but little to the eye. Experiment shows that they absorb much heat also, if the heat be associated with light. The absorbed light must show the way, as it were, for the entrance of the heat. Dr. Franklin proved what has been stated, by the observation that when different colored cloths are spread upon snow, it melts most rapidly under those which are darkest.

*How is equi-
librium of tem-
perature main-
tained?*

84. EQUILIBRIUM OF TEMPERATURE.—

It has before been stated that heat is constantly radiated from all bodies. Absorption of heat, is also universal. If any number of bodies are equally hot, they remain so, each according to its surface, imparting to the rest and receiving from all the others, taken together, the same quantity

of heat. If one is hotter than the rest, it gives faster than it receives, until the equilibrium is reached. And if, while they are thus coming to the same temperature, one is a good reflector, and therefore slow to receive the heat which comes to it, it is also slow to part with what it gets; thus the difference of reflecting power is without influence.

85. COOLING OF THE EARTH.—Were it not for the sun, the heat of the earth would waste away very rapidly into space. It is, in fact, radiated into space now, as truly as if there were no sun or stars, but these make up for the loss. At night, when the sun is below the horizon, the waste by radiation takes place very rapidly, and the earth and air grow colder in consequence. It is not simply because of the absence of the direct heat of the sun, for this is removed at once when the sun sets, while the cooling proceeds until morning. As the earth, being solid, is a better radiator than the air, it cools most rapidly, sending out its heat through the air into space. In this way the earth often becomes cooled from ten to twenty degrees lower than the air above it.

86. ICE IN THE TROPICS.—Advantage is taken of the cooling which occurs by radiation, to produce ice, in countries where the temperature of the air does not fall to the freezing point. Water contained in shallow vessels, placed in trenches dug in the ground, to protect it from currents of warm air, becomes covered with ice by a night's ex-

What is said of the cooling of the earth?

How is ice produced in the tropics?

posure. That the water is not frozen by evaporation, is evident from the fact that it does not freeze in windy nights; when evaporation is greatest.

Explain the formation of dew. 87. THE FORMATION OF DEW.—Dew does not “fall.” Its deposition is another consequence of the cooling of the earth by radiation. The air, however transparent, always contains moisture, absorbed and invisible. Cold, causes the air, like every thing else, to contract, and presses out of it, as it were, the water which it contains. Now, when at night the earth has become cooled by radiation, the warmer air which comes in contact with it is cooled, and thus made to deposit its moisture in the form of dew. When the temperature is sufficiently low, the dew takes the form of frost.

Why do clouds prevent the formation of dew? 88. WHY CLOUDS PREVENT DEW.—Clouds send back the heat radiated from the earth, by a new radiation, and thus prevent the cooling which is essential to the production of dew. No dew is found therefore, on cloudy nights, when, if it came from above, like rain and snow, we should expect most.

How can the formation of dew be prevented artificially? 89. ARTIFICIAL PREVENTION OF DEW AND FROST.—It is only necessary to substitute for clouds the artificial canopy of a muslin handkerchief, or any other covering, at a little distance from the earth, to prevent the deposition of dew and frost. Gardeners practised this method of protecting their tender plants from frost, long before philosophers explained it.

Why is dew not deposited on polished surfaces.

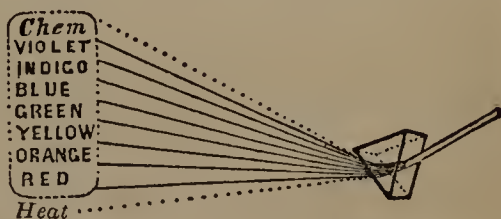
90. ABSENCE OF DEW ON POLISHED SURFACES.—Dew does not form on polished surfaces because they are poor radiators, or, in other words, do not allow their heat to escape, and thereby produce the degree of cold which is required to form dew. Leaves and grass receive most dew, because they are the best radiators.

Why does the thermometer fall when brought near ice?

91. SUPPOSED RADIATION OF COLD.—If a piece of ice be held before a thermometer, it will cause the mercury to sink. It is not because cold has been radiated from the ice, but because the thermometer, in common with all other bodies, is constantly giving out heat, and when the ice is near, it does not get its due portion in return. The ice cuts off the heat that would have come to it from other objects behind it, and gives it but little in its place.

How are rays of heat refracted?

92. REFRACTION OF HEAT.—Rays of heat from the sun and other objects, are refracted or bent out of their course, on passing from one medium to another, similarly to rays of light. By ordinary glass prisms most of the heat rays are refracted in a less degree.



What is said further of heat rays and chemical rays?

93. HEAT RAYS AND CHEMICAL RAYS.—The light which proceeds from the sun, is accompanied by rays of heat and others called chemical or *actinic* rays. In the analysis of light by a prism, the chemical rays accumulate principally in the region of the violet color of

the spectrum, while the most of the heat rays are thrown into the region of the red, and below it. Neither the place of the heat rays nor of the chemical rays is visible to the eye, but a delicate thermometer proves that there is most heat just below the red, and a piece of paper covered with chloride of silver, (a substance very sensitive to the chemical rays of light,) grows black most rapidly in the region of the violet. The place of the chemical and heat rays is thus shown, although neither can be seen. It is not to be understood that they are confined to the points indicated, but only that they are accumulated there in largest proportion.

Explain the action of burning glasses. 94. BURNING GLASSES.—The collection of rays of heat from the sun by ordinary burning glasses, depends on the fact that they are refracted, or bent out of their course on passing from one medium to another, precisely as in the case of light. A lens made of two watch-glasses, filled with water, answers for heat as well as light, and may be used as a burning glass.

Are all the rays of heat alike? 95. DIFFERENT HEAT RAYS.—There are different kinds of heat rays, as there are of light rays; some will pass through one substance best, and some through another. Thus, a piece of smoked rock salt allows the blue heat ray of the spectrum to pass, while alum lets the lower or red heat ray pass.

How is the analysis of heat effected? 96. ANALYSIS OF HEAT.—The analysis of heat is effected by the same means as that of light. Rays of the sun are passed through a prism just as if light were to be analyzed,

a dark color red glass being previously placed before the prism, to absorb the light and allow the heat only to pass. Emerging from the prism, it forms an invisible spectrum of rays beyond. These rays correspond to the different colored rays of light, and have different capacities of passing through different substances, as before stated. But, strictly speaking, they have no color; they were called blue and red, simply to designate their relative position. Heat from very intense sources is mostly violet, and violet heat passes more readily than the other rays through most substances. This accounts for the fact that the heat of the sun is not stopped by glass. For the analysis of heat from other sources other material must be employed.

97. EFFECT OF DIFFERENT HEAT RAYS

What is said of the melting of snow? IN MELTING SNOW.—Snow melts comparatively slowly in the heat of the sun, for the reason mentioned in the last paragraph.

Being from a highly heated source, it *passes through* the snow instead of stopping to melt it. But near a fallen tree melting proceeds more rapidly, because the heat absorbed as violet, is radiated again from the moderately heated source as red heat, which, falling on the snow in its vicinity, is readily absorbed, instead of being transmitted.

98. BURNING GLASS OF ICE.—A lens

How can gunpowder be ignited by ice? sufficiently powerful to ignite gunpowder may be made of ice. In using any lens, it is first to be placed near the object to be ignited, and then withdrawn till the spot of light which it casts is round and very small. The focus to which

all the rays of light converge is thus found. The heat focus is a little beyond, but so near that the difference need not be taken into account.

Section 3.—Changes effected by Heat.

99. EXPANSION, MELTING, AND VAPORIZATION are the principal changes effected by heat, while contraction, freezing, and condensation of vapor are produced by its withdrawal. But before these changes are explained, it will be well to consider certain remarkable differences in the heating effects of heat, in the case of different substances.

100. THE HEATING EFFECT OF HEAT IS DIFFERENT FOR DIFFERENT SUBSTANCES. It might naturally be supposed that the same quantity of heat actually imparted to different substances would make them equally hot but this is not the case. If two heated cannon balls, of the same size and temperature, are cooled, the one in mercury and the other in an equal weight of water, the mercury will be made much hotter than the water, by reception of the same heat. It does not simply feel hotter, as it might do if it were not really so, from the superior conducting power of the mercury, but it is actually so, as may be ascertained by testing the temperature by the thermometer.

101. SPECIFIC HEAT.—If the above experiment were varied, by cooling in mercury a bullet of one-thirtieth the bulk of that used

for the water, the two would be brought to the same temperature. Mercury requires but one-thirtieth as much heating as an equal weight of water, to make it equally hot. It fills up, as it were, with heat, more rapidly. The comparative quantity required by any substance to produce an equal elevation of temperature, is called its *specific heat*.

102. Taking water as the standard, and calling its specific heat one, that of mercury is about one-thirtieth. That of iron is about one-tenth. The specific heat of other substances is given in decimals in a table contained in the appendix.

103. RELATIVE HEAT.—If we compare equal bulks of water and of mercury, instead of equal weights, we make out the capacity of mercury for heat, to be one-half instead of one-thirtieth that of water. The comparative capacity when thus estimated for equal measures, is called *relative heat*. Thus we say that the relative heat of mercury is one-half that of water. This method of comparison is seldom employed.

104. RELATION OF HEAT AND DENSITY.—The specific heat of any substance is diminished as its density is increased. Less is required to indicate the same temperature. The surplus raises the temperature. This is one source of the heat which is produced in hammering metals. In the case of gases, the diminution is nearly proportioned to the increase of density. In the case of liquids and solids it has been less carefully investi-

gated. In the comparison of different substances, no inference as to specific heat can be made from the degree of density. A substance more dense than another may at the same time have a greater specific heat.

How does the ocean serve as a reservoir and regulator of heat?

105. THE OCEAN A RESERVOIR OF HEAT

In hot weather the ocean absorbs the heat of the sun and air. If it were an ocean of mercury, it would soon grow as hot as the air, and therefore cease absorbing; but its capacity for heat is so much greater that this does not occur. Again, in cold weather it is constantly giving out the large quantity it has absorbed, but at the same time itself grows cool, though very slowly. It is thus a reservoir of heat and a regulator of climate.

Explain the principle of the Fire Syringe.

106. FIRE BY COMPRESSION.—The fire

syringe, represented in the figure, is an instrument designed to produce fire by the compression of air. On forcing the piston suddenly down, the tinder below it is ignited. This takes place on the principle already explained. The specific heat of compressed air is less than that of air uncompressed. When the compression takes place, the surplus elevates the temperature and inflames the tinder.



EXPANSION.

107. EXPANSION UNIVERSAL.—All bodies.

What effect has heat on the size of bodies?

solid, liquid, and gaseous, expand by heat. and contract to their original dimensions on cooling. An iron wire lengthens by heat; the mercury in a thermometer expands and rises by

heating; air partially filling a bladder expands and fills it by the operation of the same cause.

How does heat operate to expand bodies? HOW HEAT EXPANDS BODIES.—All particles may be regarded as surrounded by spheres of heat. On imparting additional heat to any substance, the sphere of each atom is enlarged, and general expansion is the consequence. According to another mode of viewing the subject, heat produces repulsion between particles in some unknown way, and this occasions expansion.

Among solids, which expand the most? 109. EXPANSION OF SOLIDS.—The expansion of solids by heat is comparatively small. Among solids, the metals expand the most; but an iron wire increases only $\frac{1}{800}$ in length on being heated from zero up to 212° . Expansion in general bulk is about three times as great as in length. Thus, a cannon ball heated to 212° would occupy about $\frac{1}{270}$ more space than when cooled down to zero.

How may the expansion of metals be illustrated? 110. ILLUSTRATION.—The expansion of metals may be illustrated by arranging a brick, a knitting-needle, and a shingle, as in the figure. On heating the needle with a spirit lamp, the shingle, if before carefully poised, will be overturned.



What application of this expansion is made in the arts? 111. WHEEL-TIRES, RIVETS, ETC.—Important application of even this small degree of expansion is made in the arts. The tires of carriage wheels, for example,

are made originally too small for the frames they are to surround. They are then heated red hot and applied in a state of expansion. The contraction which afterward takes place, on sudden cooling by cold water, binds the wooden frame-work together with the greatest firmness. So in making steam-boilers, the rivets are fastened while hot, that they may by subsequent contraction unite the plates more firmly.

What disadvantages arise from the expansion of metals?

112. HOT-WATER PIPES.—In certain uses to which iron is applied, the consequences of expansion have to be carefully guarded against. A cast-iron pipe for the conveyance of steam or hot water, must not be so laid that its ends touch two opposite walls, lest by its expansion when heated, the walls should be overturned.

What effect has cold upon clamps in walls?

113. CLAMPS IN WALLS.—If the two ends of a piece of metal are fixed so that they cannot move, and contraction takes place by cold, the metal must break. Cast-iron clamps in walls are frequently thus broken. If they are of wrought iron, they often crush the stone, and thus loosen themselves in their sockets.

How are walls straightened by expansion and contraction?

114. LIFTING WALLS.—Walls of buildings in danger of falling, have been restored to their perpendicular position by taking indirect advantage of expansion. This is effected, by connecting the walls to be lifted into place, by an iron rod, fixed firmly into one wall, and passing loosely through a hole in the other. The whole length of the rod is then heated by lamps, whereby expansion is occasioned, and the rod made to

project beyond the building. The nut with which it is provided is then screwed up on the projecting rod, until it touches the outside of the wall. The lamps being then removed, the rod cools, and, by its contraction, draws up the walls with it.

115. FRACTURE OF GLASS VESSELS.—

Explain the fracture of glass vessels by heat?

Glass expands less than iron by heat, yet sufficiently, when expansion is unequal on opposite surfaces, to occasion its fracture.

Thus if hot water be poured on a thick glass plate, it cracks. The first effect is to expand the upper surface, while the under one is but slightly affected. The obvious tendency of this unequal expansion, is to warp the plate, and curve it inward toward the under side. But, as the glass cannot bend, it breaks.

116. HOW TO CUT GLASS BY HOT WIRE.

How can heat be used to cut glass?

In consequence of the same unequal expansion, a crack once commenced in glass may be made to follow the heated end of a rod of iron or pipe-stem drawn over its surface. Broken vessels of glass may be thus cut into useful shapes. A glass vial may be cut evenly in two, by encircling it with a ring of iron heated to redness, and afterward plunging it into cold water. The glass beneath the ring becomes expanded through and through, and the subsequent immersion in water, causes a sudden contraction in the exterior, and consequent fracture, on the principle above stated.

117. WOOD AND MARBLE EXPAND LIT-

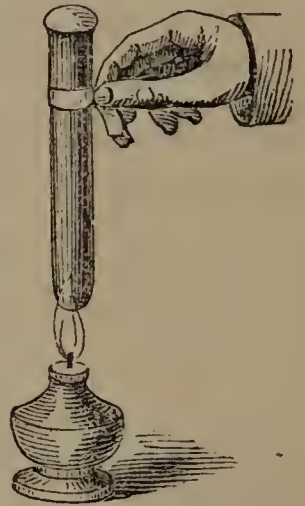
Why are wood and marble used for pendulum rods?

TLE.—Wood and marble expand but little by heat, and are therefore sometimes used for pendulum rods, where careful provision

must be made against change of length by change of weather.

What is the relative expansion of water and iron? 118. LIQUIDS EXPAND MORE THAN SOLIDS.—A column of water inclosed in a glass tube, will expand $\frac{1}{23}$ in length on being heated from freezing to the boiling point of water, while a column of iron will expand only $\frac{1}{812}$.

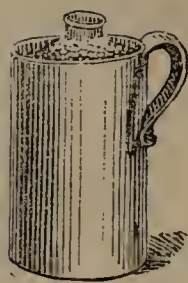
Illustrate the expansion of liquids by heat. 119. ILLUSTRATION.—The overflow of water from full vessels before boiling commences, so often observed in the kitchen, is in consequence of expansion by heat. To illustrate the expansion of liquids, a test-tube full of water may be heated over a spirit lamp, as indicated in the figure. The water will be found to heap itself into a convex surface over the mouth of the tube, and even to run over, long before boiling commences.



What effect has cold on water at 39°F. 120. COLD WATER EXPANDS BY COLD.—There is an important exception to the general law of expansion of liquids by heat and contraction by cold, or withdrawal of heat. Very cold water (39°F.) expands by further cold before it freezes. Again, on conversion into ice, it undergoes still further expansion.

How may expansion by cold be illustrated? 121. ILLUSTRATION.—Expansion by these combined causes may be shown by burying a test-tube full of water in a mixture of snow and salt. Before the water is completely frozen, it will rise at least a quarter of an inch, and fill the tube..

The greater part of this expansion is owing to the latter of the causes above mentioned. The freezing mixture employed is made of two parts snow to one part salt, brought into the cup alternately, in small portions. It is well to wrap the cup in flannel, or other cloth, to prevent loss of heat. From ten to fifteen minutes are required for the experiment. If the water is perfectly frozen, the tube will be cracked by its expansion.



Why does cold water float on warmer water?

122. COLD WATER FLOATS ON WARMER WATER AND PROTECTS IT.—It was shown in the last paragraph that very cold water (below 39°) is in an expanded condition, and occupies more space than warmer water. It follows that it is lighter, and will float on warmer water. As the weather grows colder each winter, and the time approaches for the formation of ice in rivers and lakes, the cold water does actually float on the warmer, and protect it from the cold air. The body of water being thus protected, ice never forms many feet thick. The case would be very different if water grew constantly heavier by cold. The surface water would then constantly sink, until all were reduced to the freezing point. Cooling does, in fact, proceed in this way until the temperature sinks to 39° ; then the exception comes in play, and the surface water, as before stated, retains its place and exerts its protecting influence. When ice is subsequently formed it has the same effect.

123. CONSEQUENCES OF THE LIGHTNESS

What consequences result from the expansion of water by cold?

OF VERY COLD WATER.—But for the remarkable fact that more cold makes very cold water lighter, and not heavier, and thus enables it to exert the protecting influence just explained, the cold of a single winter would be sufficient to kill all the fishes inhabiting our lakes and rivers. Another consequence would be change of climate, as a necessary result of the formation of immense masses of ice, which the heat of the summer would be insufficient to melt. The temperate regions of the earth would thus become uninhabitable. Such are the consequences which are obviated by this remarkable exception to a general law of expansion. The whole realm of nature furnishes no more remarkable evidence of design on the part of the CREATOR.

124. SOME LIQUIDS EXPAND MORE THAN

In what proportion do spirits of wine, oil, and water expand?

OTHERS.—Some liquids expand more by heat than others. Spirits of wine, on being heated from 32° to 212° , increases one-ninth in bulk; oil expands about one-twelfth, and water, as has before been stated, one-twenty-third. It is much to the advantage of the dealer in spirits to buy in winter and sell in summer. Twenty gallons bought in January, will have become, by expansion, twenty-one in July. The difference between the coldest and warmest weather of the year, is sufficient to make about this difference in bulk.

125. GASES EXPAND MORE THAN EITHER

How do gases compare with solids and liquids in expansibility?

SOLIDS OR LIQUIDS.—Gases expand more than either solids or liquids by heat. The reason is, that in gases there is no co-

hesion to overcome as in the two other states of matter. While iron increases in general bulk $\frac{1}{270}$ th, and water about $\frac{1}{3}$ d, on being heated from the freezing to the boiling point of the latter, air expands more than $\frac{1}{3}$ d by the same increase of temperature.

126. LAW OF EXPANSION FOR GASES.—

State the law of expansion for gases.

Gases expand $\frac{1}{490}$ th of the bulk which they possess at 32° , for every degree above that point, and contract in the same proportion for every degree below it. Thus, 490 cubic inches at 32° would so expand as to occupy an inch more space at 33° , still another inch at 34° , and at the same rate for higher temperatures. And the same quantity would contract by cold, or withdrawal of heat, so as to occupy an inch less space at 31° , and two inches less at 30° , and so on for lower temperatures. The law is the same for steam and other vapors.

What is a thermometer?

127. THE THERMOMETER.—The thermometer is an instrument in which expansion is made use of to show changes of temperature. A straight wire, which would grow regularly and perceptibly longer in proportion to the increase of temperature, would form the most convenient thermometer. But solids do not expand enough, or with sufficient regularity, for this purpose. The liquid metal mercury, is therefore employed instead, being inclosed in a glass tube and bulb.

How are thermometers manufactured?

128. CONSTRUCTION OF THERMOMETERS.—In making thermometers, the mercury being first introduced into the bulb, is boiled, so as to expel all air and moisture,

and fill the tube with its own vapor. The end of the tube is then closed by fusion. As the metal cools, it contracts and collects in the bulb and lower part of the tube, leaving a vacuum above. The instrument is now complete, with the exception of graduation. Used in this condition, the mercury would be observed to rise and fall with changes of temperature, but we should not be able to say how much or how little.

129. GRADUATION OF THERMOMETERS.—

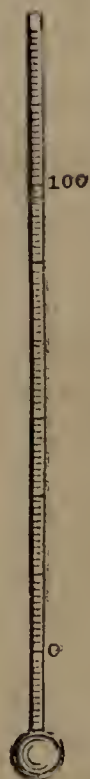
*How are
thermometers
graduated?*

To obtain a fixed point from which to count, the instrument is immersed in melting ice, and the point to which the mercury sinks scratched on the glass. This point is called *zero*. Another fixed point is obtained by immersing the thermometer in boiling water, and when the mercury has risen, noting this height also on the glass, and marking it 100° . The space between the two points is next divided into one hundred equal parts, by scratches on the glass, and numbered from one up to a hundred. The upper and lower portions of the tube are marked off into divisions of the same length, for very high and low temperatures.

130. CENTIGRADE THERMOMETER.

*Describe the
Centigrade
thermometer.*

A thermometer graduated as above is called a centigrade thermometer, from the fact that the space between “boiling” and “freezing” is divided into one hundred degrees. This is by far the most rational method of graduating, and these thermometers are in general use on the



continent of Europe, and by scientific men all over the world.

Describe the Fahrenheit thermometer. 131. FAHRENHEIT THERMOMETER.—This is the thermometer in common use in this country. The instrument itself is precisely the same as the centigrade. The difference is only in the graduation. In graduating it, the space between the freezing and boiling points having been marked on the glass, is divided into one hundred and eighty parts, and the rest of the tube, above and below, into similar spaces. The zero, or starting point, is fixed lower down than in the centigrade, where nothing especial happens, instead of where water freezes. The consequence is, that in counting up and affixing the numbers, the freezing point comes at 32° , and the boiling point at 212° . There is no good reason for placing the zero there, or for choosing such a number as 180 for the number of degrees between freezing and boiling. The centigrade graduation is, therefore, much to be preferred. If a thermometer of each kind were immersed in boiling water, the mercury would rise in the centigrade to the point marked 100, and in the Fahrenheit to the point marked 212. In the same way, *zero* centigrade corresponds to 32° Fahrenheit. The two thermometers are compared in the figure.



How is extreme cold measured?

132. EXTREME COLD, HOW MEASURED. As the temperature is lowered, the mercury of the Fahrenheit thermometer sinks, until by

sufficient cold it reaches 39 degrees below zero. More intense cold has no further effect, for at this point the mercury freezes. How much colder it is than -39° cannot be told, therefore, by the mercurial thermometer. Thermometers containing alcohol instead of mercury are used for this purpose, because alcohol never freezes, and will continue to sink further and further in the tube the colder it grows.

133. EXTREME HEAT, HOW MEASURED.

*How is extreme
heat meas-
ured?*

If a Fahrenheit thermometer is heated, the mercury in it rises till it reaches 662° , and then begins to boil. A little more heat forms sufficient vapor of mercury to burst the tube. For this reason, a mercurial thermometer cannot be used to measure extreme heat. A platinum bar inclosed in a black lead tube shut at the bottom, is commonly employed for this purpose. Tube and bar are placed on the fire, or in the melted metal, whose heat it is desired to measure, one end being left out, so that it can be seen. The consequence is that the platinum bar expands, and projects from the earthen tube. The tube itself expands but little. The further the bar projects, the greater is the heat. As it pushes out, it is made to move an index hand, and point to the number indicating the temperature, on a graduated arc. This arc is first graduated by repeated trials, observing how much the bar projects and moves the hand by the same heat which raises the mercury one degree in the Fahrenheit thermometer.



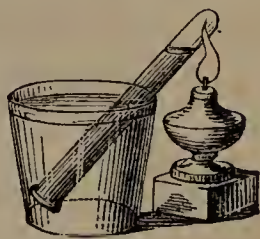
134. THE AIR THERMOMETER.—A col-

*Describe the
air thermome-
ter.*

umn of air confined in a glass tube over colored water, was the first thermometer

used. Heat expands the air and lengthens the column downward, pushing the water before it, while cold has the contrary effect. The temperature is thus indicated by the height at which the water stands.

Illustrate the principle of the air thermometer. 135. ILLUSTRATION.—The principle of the air thermometer may be illustrated as represented in the figure. A test-tube is half filled, and then inverted in a glass of water without allowing the water which it contains to flow out. Heat applied to the tube will lengthen the column of air by expansion.



LIQUEFACTION.

How do solids become liquids? 136. SOLIDS BECOME LIQUIDS BY HEAT. On being heated up to a certain point, solids are melted, or converted into liquids. Thus, at all temperatures below 32° , water is solid ice, but the moment it is warmed up to this point, by change of weather or other means, it begins to melt. The temperature at which this change occurs is called the melting point. 32° is therefore the melting point of ice. The melting point of sulphur is 226° ; that of lead, 612° .

Are all substances fusible? 137. ALL SUBSTANCES ARE FUSIBLE.—All substances are fusible, or, in other words, may be melted; but the melting point of all is not definitely known. Thus carbon has been fused by the heat of the galvanic battery, but it is impossible to state the melting point in degrees.

Under great pressure, increased heat is required to effect fusion. Thus the melting point of sulphur is raised from 226° to 285° , by a pressure of 11,880 lbs to the square inch. There are exceptions to this law.

What remarkable circumstance attends the melting of bodies?

138. **DISAPPEARANCE OF HEAT IN MELTING.**—Melting or fusing is effected by heat and a remarkable circumstance attending it, is the disappearance of the heat which

has effected the change. Thus, if a thermometer be applied to ice or snow which has just begun to melt it will be found to stand at 32° . Let the ice be then introduced into a tumbler, and placed on a stove, and the temperature again tested at the moment when the conversion into water is completed. The thermometer will be found again to stand at 32° . The water produced is no hotter than the original ice, yet heat has been pouring into it, through the bottom of the vessel, during the whole process of melting. If a piece of glass of the same size had been subjected to the same heat, it would have grown constantly hotter. It follows that in the case of the ice there has been a disappearance of heat. This disappearance always occurs whenever a solid is converted into a liquid.



What other instances of disappearance does chemistry afford?

139. **ANALOGOUS DISAPPEARANCE OF ACIDITY.**—Chemistry furnishes other instances of disappearance, which may help us in understanding this one. If vinegar

be poured upon chalk it loses its sourness. It is because a combination has taken place between the acid

vinegar and the lime which the chalk contains, and a new substance, called a salt, has been formed out of both. So in the present case, we may suppose that heat and the solid have combined to form a liquid, and the property of heat to effect the senses and the thermometer, has at the same time disappeared. Any liquid may therefore be regarded as a compound of solid and heat. The heat which thus disappears is called *combined*, or *latent heat*.

Mention some freezing mixtures. How do they produce cold?

140. FREEZING MIXTURES.—When solids take a liquid form by other means, as, for example, when salt dissolves in water, the temperature is generally much reduced.

Nitre, for example, reduces the temperature of water in which it is dissolved from 15 to 18 degrees, and is therefore much used in the East, where it is abundant, for cooling wines. Mixed nitre and sal-ammoniac have a still greater effect. Sulphate of soda drenched with strong muriatic acid, will reduce the temperature from 50° to zero.

Mention other freezing mixtures. Why do they produce greater cold?

141. When two solids, on being mixed, become both liquid, still greater cold is often produced. This is the case with a mixture of snow with common salt, or with chloride of calcium. By the former mixture, used as shown in paragraph 121, ice cream is frozen.*

By the latter mixture, a cold sufficient to freeze mercury may readily be produced. For this purpose, three parts of the salt are to be mixed with two of dry snow.

* Fahrenheit regarded the temperature thus produced as absolute cold, and therefore assumed it as the zero of his scale.

142. THE MELTING OF SNOW COOLS THE

How does the melting of snow affect the weather?

AIR.—Whenever ice is converted into water, whether rapidly by fire or slowly by change of weather, the disappearance of heat, above mentioned, occurs. Thus, when the snow melts in spring, heat is drawn off from the air and made latent, or combined in the water which results from the melting. This makes the weather cooler than it would otherwise be, and retards in a measure the advance of spring.

How do liquids become solids?

143. FREEZING.—Liquids become solids

by the removal of their combined heat. Thus, if molten lead be allowed to stand awhile, the heat which it contains passes away into other objects, warming them; and the metal itself, having lost its heat, becomes solid. So in winter, the combined heat which is contained in water, is conveyed away by the colder air, and the water, having lost its heat, is converted into ice.

What is the freezing point of a liquid?

144. FREEZING POINT.—The tempera-

ture at which a substance passes from the liquid into the solid state is called the freezing point. Thus, 32° is the freezing point of water. The freezing point of any substance is, as might be supposed, the same as the melting point. Water, for example, becomes ice in process of cooling, at the same temperature that ice becomes water in process of heating.

Can all liquids be frozen? Give examples.

145. ALL LIQUIDS HAVE THEIR FREEZ-

ING POINT. — There is good reason to believe that all liquids, without exception,

have their freezing point, but the reduction of temperature requisite has not in the case of all been attained. Alcohol and ether, for example, have never been frozen.

In freezing, what becomes of the latent heat? 146. IN FREEZING, LATENT HEAT BECOMES SENSIBLE HEAT.—If water, in sufficient quantity, is taken into an apartment whose temperature is several degrees below the freezing point, and then allowed to become ice, it will be found that the freezing process has actually warmed the apartment several degrees. The latent heat has been drawn off by the colder air of the room, raising its own temperature, and leaving the water in the condition of ice.

How can cellars be warmed by ice? 147. CELLARS WARMED BY ICE.—In accordance with the principle above stated, tubs of water are sometimes set to freeze in cellars, thereby to prevent excessive cold. And even in the coldest climates a sufficient supply of water might thus be made to secure an apartment against extreme cold.

What effect has the freezing of water on climate? 148. EFFECT ON CLIMATE.—The milder climate of the vicinity of lakes which are accustomed to freeze in winter, and the moderation of the weather during a snow storm, are accounted for on the same principle. As the melting of snow retards in a certain degree the advance of spring by the heat it abstracts from the atmosphere, so the formation of ice tends to make the advance of winter less rapid, by the heat which it evolves.

VAPORIZATION.

What is said of the formation of vapors?

149. FORMATION OF VAPORS.—Unlike melting or liquefaction, vaporization occurs gradually, and through a wide range of temperature. Thus water at all temperatures, and even ice, yields vapor. But there is a limit for each substance below which its evaporation does not occur.

What is the appearance of vapors?

150. VAPORS TRANSPARENT.—All vapors are perfectly transparent, like the atmosphere. If water is boiled in a flask, it will be found that the steam within the flask is as transparent as air. The steam thrown from a locomotive would be invisible if it remained steam. We should hear its roar, but see nothing.

Is the density of vapors uniform?

151. DENSITY OF VAPORS.—Vapors are of all degrees of density. The vapor of water may be as thin as air, or, again, almost as dense as water itself.

Illustrate the elasticity of vapors.

152. ELASTICITY OF VAPORS.—All vapors are elastic, like air. Steam, like air, if compressed in a cylinder, with a close fitting piston, by a heavy weight, would expand again, and force the piston out, as soon as the weight were removed. The force with which a vapor expands, or strives to expand, supposing the weight not removed, is called its *elastic force* or *tension*.

How does temperature affect density?

153. DENSITY DEPENDS ON TEMPERATURE.—The vapor produced at ordinary temperatures by evaporation from the sea and the moist earth, is less dense, or, in other words, contains less water in the same volume, than that formed during the heat of summer. Ordinary steam, or aqueous vapor, produced at 212° , has still greater density. Steam produced at 250° has double the density of ordinary steam, and by increasing the temperature to 294° , the density is again doubled. Steam of higher temperature than 212° can only be produced in closed vessels, or those with an imperfect vent. The law is the same in the case of other vapors—the higher the temperature the greater the density, provided a surplus of the material from which the vapor is produced is present. But if this is not the case, heat has simply the effect of expanding the vapor as it would an equal quantity of air. In the case of a partial supply of water, the vapor grows more dense, but does not reach the highest density which it would have at the same temperature with a full supply.

What remarkable circumstance attends the formation of vapors?

154. DISAPPEARANCE OF HEAT IN VAPORS.—The same disappearance of heat which occurs when a solid is converted into a liquid, occurs also when a liquid is converted into a vapor or gas. Thus, if we wish to cool a room in summer, we sprinkle the floor. As the water evaporates, much of the heat of the room disappears. It has entered into combination with water to produce vapor, and has no longer the power of af-

fecting the senses and the thermometer. In the same manner, our bodies are cooled in summer by the constant evaporation of moisture from the surface. All vapors may, indeed, be regarded as combinations of heat with the liquids from which they are formed. In this case, also, the heat which becomes latent in thus combining, is called latent heat.

*How can ether
be made to
freeze water?
Explain its
action.*

155. FREEZING BY EVAPORATION.—The more rapidly a substance evaporates, the more heat does it require for the evaporation. This it obtains from objects in contact with it. Ether may be made to evaporate so rapidly as to freeze water, even in summer. This is best accomplished by covering the bottom of a test-tube with a cotton rag, or several layers of porous paper, as represented in the figure, dipping it into ether, and then waving it to and fro in the air, or spinning it between the palms of the hands. By repeating this process several times, a few drops of water, previously placed in the tube, may be frozen. A mixture of liquefied carbonic acid and nitrous oxide gases, previously liquefied, produce on evaporation a temperature of 220 degrees below zero.



How does evaporation protect from heat?

156. PROTECTION FROM HEAT BY EVAPORATION.—By previously moistening the fingers, they may be dipped unharmed, for an instant, into molten lead, or passed through a stream of white-hot iron as it flows from the furnace. A cloak of comparatively cool vapor is formed from the moisture upon the fingers, and keeps them from contact with the molten metal.

157. RELATIONS OF AIR AND VAPOR.—

*Does vapor
displace air?*

The earth is surrounded by air to the depth of fifty miles. It is also surrounded by vapor occupying the same space which the air occupies. But they are independent of each other. Each contracts for itself, and expands for itself, according to the temperature. When more vapor is produced by evaporation from the sea, or other sources, it rises into the air without displacing it or pushing it aside, only rendering the vapor which it before contained more dense.

158. QUANTITY OF VAPOR IN THE AT-

*What quanti-
ty of vapor
exists in the
air?*

MOSPHERE.—The air is always *full* of vapor; that is, where there is a cubic inch of air, there is a cubic inch of vapor with it, occupying the same space.

159. QUANTITY OF WATER THE AIR MAY

*Upon what does
the quantity of
water in the air
depend?*

CONTAIN AS VAPOR.—As the density of vapor is dependent on temperature and the supply of material to be vaporised, it is obvious that the quantity of water present in the air in the form of vapor, varies according to temperature and locality. In summer, and over the sea, it is commonly greatest. At a medium summer temperature of 75 degrees, the vapor in the air is sometimes so dense that every cubic yard of air contains a cubic inch of water, in this form. But it can never, at this temperature, contain more. It is then said to be “saturated,” and also that its capacity for water is filled.

What effect has heat upon the quantity of vapor present in the air?

160. CAPACITY OF THE AIR FOR WATER INCREASED BY HEAT.—As the weather grows warmer, the capacity of the air for moisture is increased, so that at 100° , it can contain twice as much as at 75° , or two cubic inches. On the other hand, as the weather grows cooler, its capacity is diminished, so that at 50° it can hold scarcely more than half a cubic inch, and is saturated by this comparatively small quantity. And, in general, the capacity of the air for moisture is increased by the elevation of its temperature.

How does wind affect the quantity of vapor in the air?

161. EFFECT OF WIND.—Wind causes evaporation to proceed more rapidly, not because the air in motion has any greater capacity for moisture, but because new portions of air are brought successively into contact with the wet surface. As fast as one portion has imbibed a certain amount of moisture, another portion of drier and more thirsty air takes its place.

Explain the deposition of moisture.

162. DEPOSITION OF MOISTURE.—It follows that air that is saturated, or, in other words, has its full portion of moisture in the form of vapor, must deposit a portion of it in the form of water in cooling. Thus a cubic yard of saturated air at 75° , on being cooled down to 50° , would yield half a cubic inch of water, or half of the whole quantity which it originally contained. If we suppose the experiment to be performed in a glass vessel where the effect of cooling could be observed, we should first see a mist or dew within the box, consisting of the particles of water which the colder air can

no longer retain. This mist would gradually deposit and collect in the form of water, and if measured, would be found to make more than half a cubic inch. Something less than half a cubic inch would remain as invisible vapor in the cooled air. If the air were cooled further, part of this would be condensed to water.

What is said of unsaturated air and its moisture? 163. UNSATURATED AIR.—Air that does not contain its complement of water will not yield any by slight cooling. It would be like slightly compressing a half-filled sponge. But as the cooling proceeds, the vapor becomes so dense that further cooling will cause a deposition of moisture. A cubic yard of air at 75° , containing only half a cubic inch of water in the form of vapor, would yield none on being cooled down to 50° . At this point the formation would commence. If it contained originally less than half a cubic inch, it would have to be cooled still lower before any moisture made its appearance. The less the moisture, in short, the more cold it would require to wring it out.

Is the quantity of vapor in the atmosphere always proportioned to its warmth? 164. QUANTITY OF VAPOR IN THE ATMOSPHERE.—As has been already stated, the capacity of air for vapor is in proportion to its warmth. The air of summer can therefore contain more than that of winter; and it frequently does so. But this is not necessarily the case, for the capacity for moisture is not always filled. Hot air over a desert, for example, contains less moisture than cold air over the sea. And in the same locality, and during the same season, the quantity of

moisture in the air will differ from day to day, and from hour to hour. This will depend a good deal on the wind, whether it blows from the land or from the sea. Sometimes it contains a cubic inch of water in the form of vapor in every square yard, but generally less.

What is the cause of mists and fogs? 165. MIST AND FOG. — These are aqueous vapor, rendered visible by the cooling of the air, as before explained.

When the air is saturated, the least cooling will produce a fog, as in the case supposed in paragraph 162. When it is not saturated, more cooling will be required, as in the case supposed in the subsequent paragraph. The beautiful veil of mist, which forms in summer nights over low places, is owing to the cooling of the air below its point of saturation, which takes place after sunset.

Explain the production of fogs by mixed currents of air. 166. MIXED CURRENTS OF AIR.—The phenomena of mist, fog, clouds, and consequently of rain, are more commonly owing to the mixture of cold and warm winds or currents of air. When this admixture takes place, the warm air becomes colder, and tends to deposit its moisture, and the cold air warmer; and it might be at first supposed that those two influences would counteract each other. For example, if a cubic yard of air at 100° mixes with a cubic yard at 50° , they both become 75° , and it might be thought, that the warming of the colder cubic yard would increase its capacity for moisture, as much as the cooling of the warmer cubic yard would diminish its capacity, and

that consequently no mist would be produced. But, as before stated, it has been ascertained by experiment that hot air at 100° will contain about two cubic inches, and air at 50° , about half a cubic inch of water. The two would therefore contain two and a half cubic inches. But air at 75° can hold but one cubic inch, and consequently the two cubic yards would hold but two cubic inches. The surplus half inch would consequently take the form of visible moisture, called cloud, fog, or mist, according to circumstances. It is not to be understood, from what is above stated, that half a cubic inch of water is always yielded by every two cubic yards of air at 50° and 100° which come together ; if they are not totally saturated, the quantity will be less.

Why are fogs produced on the sea coast? 167. FOGS ON THE SEA COAST.—The sea is cooler than the land in summer, and warmer in winter. As a consequence, the air above the sea is cooler in summer and warmer in winter, than that above the land. The admixture of these bodies of air, which takes place along the coast, produces fogs on the principle above stated.

Why do fogs form on rivers? 168. FOGS ON RIVERS.—When land and water have the same temperature, as may be the case with small lakes and rivers, the difference of radiation during a single night often produces fogs. The land cools more rapidly than the water. As a consequence, the air above the land is cooler than that above the water. As the two bodies of air mingle, fog is produced, and is seen following

the devious course of the river, or brooding over the lake in the morning.

What causes the Newfoundland fogs? 169. NEWFOUNDLAND FOGS.—The fogs on the banks of Newfoundland are owing to the mixture of cold winds from the north, with the warm air of the gulf stream, which passes along that part of the ocean.

Why are clouds produced on high mountains? 170. CLOUD-CAPPED MOUNTAINS.—The temperature of the air at high elevations is always lower than at the general level of the earth. As the warm breeze comes up from the warmer valleys, the two currents mingling, produce clouds. A clear atmosphere throughout a whole day is rare, on high mountains.

What is the dew point? 171. DEW POINT.—It has been already seen that air has to be cooled more or less before it yields moisture, according to the amount which it contains. If it contains about one cubic inch to the cubic yard, or, in other words, is saturated, the least cooling will cause the appearance of visible moisture. If it contains half as much, it must be cooled down to 50° F. If it contains less than half as much, still more refrigeration is required. The temperature at which the deposition begins in any case is called the *dew point*.

How can the dew point be found? 172. HOW TO FIND THE DEW POINT.—It is commonly found by adding ice, little by little, to a glass of water containing a thermometer. As the water grows cool, the glass cools also, and as a



consequence, the exterior air immediately in contact with it. After a time, moisture begins to deposit. The temperature at which this occurs is noted, and is the dew point.

Explain the formation of dew. 173. DEW.—The earth cools, as has before been stated, every clear night, by radiation. The air in immediate contact with it, becomes thereby so much cooler, that it cannot retain all its water in the form of invisible vapor, and the deposition of the surplus in the form of dew is the consequence.

Why do grass and foliage receive the most dew? 174. Grass and foliage receive most dew because they are good radiators, and losing their own heat most rapidly, cool down the air sufficiently to cause a deposition of its moisture. The soil itself, and stones, receive less, or none at all, because they do not, by their own radiation, become sufficiently cool to produce the same effect. Dew does not form on a cloudy night, because the clouds radiate heat to the earth and thus prevent the requisite cooling.

How is it known that the increased capacity of air for moisture is not due to expansion? 175. CAPACITY FOR VAPOR: EXPANSION NOT THE CAUSE.—It must not be supposed that the increased capacity of air for vapor, which results from heating, is owing to its expansion. Air does indeed expand about one-twentieth between 50° and 100° , but its capacity for moisture is quadrupled by the same rise of temperature.

*What proves
that absorption
is not the cause?*

176. ABSORPTION NOT THE CAUSE.—It is not uncommonly supposed that the air acts to absorb vapor as a sponge does to draw up water. The term “*saturated*,” used for convenience in scientific works, is calculated to give this impression. But vapors are found to rise, even more rapidly, into a vacuum, or space from which all the air has been removed.

*What then is
the cause?*

177. INCREASED DENSITY OF VAPOR THE CAUSE.—The air receives any vapor that may be formed, whether more or less dense. At higher temperatures, denser vapor is produced. It follows that the air will contain more water, in proportion to the elevation of its temperature.

*Does the removal
of air influence
the formation
of vapor?*

178. REMOVAL OF AIR DOES NOT INCREASE THE QUANTITY.—It might be supposed that more water would rise into a vacuum in the form of vapor than into a space filled with air, on the ground that the removal of the air would make more room for something else. It is found, however, that the presence or absence of air makes no difference in the quantity.*

*Do vapors and
gases exclude
each other?*

179. SEVERAL VAPORS MAY OCCUPY THE SAME SPACE.—It follows from the last paragraph that vapors do not displace the air; they penetrate it instead. And it is a remarkable fact, that a number of vapors may occupy the same space without interfering with one another; and each in the same quantity as if the rest were absent.

* This statement relates to vapors rising into a confined space. In unconfined space, expansion of the mixture occurs, which is equivalent to displacement in the same proportion. (§ 181.)

Give examples. 180. As much water will rise in vapor into a jar of air as if it were a vacuum. And in addition to this, as much alcohol and ether successively, as if the jar were entirely empty.

Why is moist air lighter than dry air? 181. If the elastic force or tension of air is increased, it expands. Vapors possess elastic force as well as air. A mixture of air and vapor has the combined tension of both. The tension of aqueous vapor at 80° , being $\frac{1}{30}$ th that of the air, it produces, on rising into the air, an expansion of $\frac{1}{30}$ th.* As the weight of the air is not increased in the same ratio, ordinary moist air is lighter than dry.

BOILING.

How can it be proved that the atmosphere has weight? 182. WEIGHT OF THE ATMOSPHERE.—As an introduction to the subject of boiling, it will be necessary to consider the pressure of the atmosphere. The earth is surrounded by an atmosphere, estimated to be fifty miles high. It is very light compared with the earth itself, or with water. But it has weight, as may be proved by weighing a bottle full of air, and then pumping out the air and weighing it again. The empty bottle will be found to weigh less than the bottle full of air.

Give another proof that air has weight. 183. ANOTHER PROOF OF THE WEIGHT OF THE AIR.—That the air has weight, is again proved by tying a piece of bladder

* Steam at 212° having tension equal to that of the air, would double the volume. Gases and vapors, with the density they possess when collected in the usual manner, by displacement of mercury or water, would have the same effect, and thus, like steam, displace their own volume of air.

over a glass cylinder, open at both ends, placing the open end air-tight on the plate of an air pump, and then exhausting the air. The pressure of the column of air that stands on the bladder is sufficient to break it, and the air settles in, as effectually as if it were a column of iron. The atmosphere exerts such pressure, amounting to about fifteen pounds to every square inch, on all parts of the surface of the earth.

184. A SIMPLE MEANS OF PROOF.—

Describe a simple means of proving that air has weight.

Wind a stick with cotton and press it to the bottom of a test-tube, containing enough water thoroughly to moisten it. It will be found difficult to withdraw the piston. The difficulty arises from the fact that the column of air which rests upon it, must be lifted at the same time. Having raised it a little way and released it, the piston flies with force to the bottom, owing to the weight of the same column of air.



185. ELASTIC FORCE OF THE ATMOSPHERE.

Whence does the air derive its elastic force?

Every cubic inch of air at the surface of the earth, may be likened to a piece of india-rubber, which has been compressed into the space of a cubic inch, by a heavy weight placed on it. If we suppose a piece of rubber, while thus compressed, to be confined in a strong metallic box, it would evidently exert an elastic force in all directions, equal to the force which compressed it. So the lower portions of air, which are kept compressed by the air above, exert elastic force. And it is better to regard the pressure of fifteen pounds on every square inch of

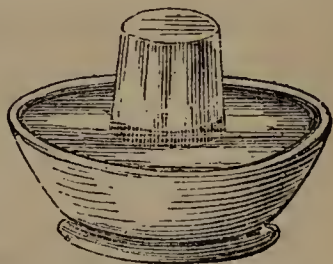
the surface of the earth, as a consequence of the elastic force of the lower portions of air, rather than the direct effect of the weight of the whole air. The weight of the whole atmosphere produces the elastic force of the lower portions by compressing them, and the elastic force of the lower portions exerts the pressure.

Why are we not crushed by the pressure of the atmosphere?

186. WHY THE PRESSURE OF THE AIR DOES NOT CRUSH US.—If a thin glass vessel were turned upside down, and air-tight, upon a table, it would collapse but for the fact that it is filled with air, which, according to the last paragraph, has elastic force equal to that of the air without. So our bodies would collapse, but for the fact that our lungs, and all of the cavities of the body, are filled with air, possessing the same elastic force as the external air; a force which it had acquired by compression, before it was taken into our bodies.

What sustains the water in the inverted tumbler represented in the figure?

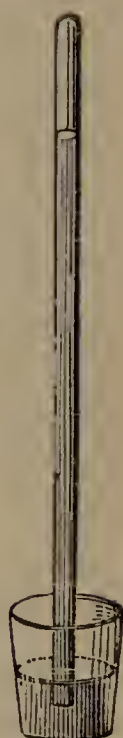
187. QUANTITY OF WATER THE PRESSURE OF THE AIR WILL SUSTAIN.—If a tumbler is filled under water, and then lifted to the surface, as represented in the figure, it is well known that the water will not run out. The pressure of the atmosphere on the surface of the water outside, keeps the water forced up on the inside.



What quantity of water will the air sustain?

188. The effect would be the same if the tumbler were twice as tall, or if we suppose it lengthened into a tube thirty-three feet long. If a still longer tube

were used, it would be found that the level of the water inside, would never be more than thirty-three feet above the level outside. The remainder of the tube would be empty, as represented in the figure. In other words, the pressure of the atmosphere will sustain a column of water thirty-three feet high. Water rises in a pump from this cause.



189. QUANTITY OF MERCURY THE

How many inches of mercury will the air sustain?

PRESSURE OF THE AIR CAN SUSTAIN.

In performing the experiment of the last paragraph with mercury, it will be found that the level within the tube, will be *thirty inches* above the external level. In other words, the pressure of the atmosphere will sustain a column of mercury thirty inches high.

Explain the Torricellian vacuum.

190. If a long tube is used, there is, of course, an empty space above. This is called the Torricellian vacuum, from the

fact that a vacuum was first produced in this manner by an Italian philosopher, named Torricelli. It is not an absolute vacuum, a small portion of mercury being always present in the space in the form of transparent vapor.

What is meant by the term boiling?

191. BOILING.—Thus far we have considered solely the formation of vapors from the surfaces of liquids. But where any

liquid is heated up to a certain point, vapor forms in bubbles below its surface. The production of vapor with ebullition is called boiling.

*What is the
boiling point
of water?
Of ether?
Of alcohol?*

192. Water begins to boil when it is heated up to 212° ; alcohol, at 173° ; and ether, at 96° . As the proper temperature is first reached at the bottom of the vessel, near the fire, the formation of bubbles begins there; and as the surplus heat comes in below, they continue to be formed at this point. Every liquid has its own boiling point.

*How much
steam do cubic
inches of wa-
ter, alcohol,
and ether re-
spectively pro-
duce?*

193. **EXPANSION IN BOILING.** A cubic inch of water boiled in an open vessel, produces 1696 cubic inches of steam. A drop one-tenth of an inch in diameter would make enough to fill a sphere of the diameter of one and a fifth inches. A cubic inch of alcohol produces about 500 cubic inches of alcohol vapor; one of ether about 250. The ether vapor is most dense, that of alcohol next, and the steam least so.



*What is said
of the disap-
pearance of
heat in boiling?*

194. **DISAPPEARANCE OF HEAT IN BOILING.**—If a thermometer is held in boiling water, it indicates a temperature of 212° F. Continue the fire, and although heat constantly passes up into the water through the bottom of the vessel, it grows no hotter. The steam which is produced has



also precisely the same temperature. Neither water nor steam is hotter, although both have been constantly taking in heat. But the heat has not been without effect, any more than in the conversion of a solid into a liquid. It has combined with the liquid to *form the steam*. In this case, also, the heat which disappears is called latent heat.

195. RELATION OF PRESSURE TO BOILING.—In order that a bubble of steam may form, it is necessary that a small portion of water, shall expand into a comparatively large portion of steam to form it. But the atmosphere is constantly pressing on the surface of the water, and acting through the water, in all parts of the vessel, to prevent any separation of particles or expansion. The case is similar to that of a piece of india-rubber compressed beneath a mass of iron: it cannot expand owing to the weight of the iron.

196. HEAT OVERCOMES PRESSURE.—But if we could by some means increase the elasticity of the india-rubber, it would expand and lift the iron. So, if we can in any way increase the tendency of the particles of water to separate, it will finally be strong enough to overcome the pressure of the atmosphere above and affect separation. Heat has this effect. As the water becomes hotter, the tendency of its particles to fly apart becomes greater and greater, till, at last, it is sufficient to overcome the pressure which has before crowded them together, and a bubble of steam is formed. Others immediately follow, and boiling thus commences. This

takes place at 212° Fahrenheit, which is therefore called the *boiling point* of water.

197. EFFECT OF HEIGHT ON BOILING.

*What effect
has height on
boiling?*

At great elevations, the atmosphere is, in fact, lighter, and there is less of it above us, and the consequence is that water boils on mountains, at a lower temperature than in the valleys below. It is found, by careful observation, that an elevation of five hundred and fifty feet above the level of the sea, makes the difference of one degree in the boiling point.

198. MEASUREMENT OF ALTITUDES.—

*How can the
height of
mountains be
determined?*

This fact once established, a tea-kettle and a thermometer are the only requisites for taking the height of a mountain. The summit being reached, the tea-kettle is boiled, and the heat of the water tested by the thermometer. If the mercury stands at 211° , it is known that the height is 550 feet; if at 210° , the height is 1100 feet; and at whatever point it stands, it is only necessary to multiply 550 by the number of degrees depression of the mercury below 212° , to ascertain the elevation. On the top of Mont Blanc, water was observed by Saussure to boil at 184° . This gives us the means of calculating very closely the height of that mountain.

199. EFFECT OF DEPTH ON BOILING.—

*What effect
has depth on
boiling?*

In mines the atmosphere is heavier, and there is, beside, more of it above us, than at the surface of the earth. Water must, in consequence, be more highly heated before it will boil. 550 feet makes, as before, a difference of one degree. We are thus provided with a simple means of determining the

depth of mines. Owing to various causes, the atmosphere at the same elevation is a little heavier some days than others, so that the height of a mountain or the depth of a mine, as thus measured, would not be always precisely correct.

200. ARTIFICIAL CHANGE OF BOILING

How can the boiling point of liquids be changed?

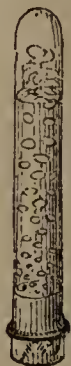
POINT.—It is obvious, from what has already been stated, that all it is necessary to do to change the boiling point, is to change the pressure of the atmosphere, on the surface of the water to be boiled. To produce this change of pressure, it is not necessary to ascend mountains, or to descend into mines; it may be done by removing the atmosphere by artificial means. This would be done by attaching a tube, air-tight, to the mouth of a test-tube or flask and drawing off the air by means of an air pump. Cold water may thus be caused to boil. So by pumping more air into the flask, the pressure would be increased, and the boiling point elevated; and by this means boiling water would be prevented from further boiling. This subject is further considered in paragraph 204.



Describe the culinary paradox?

201. CULINARY PARADOX.—Boil some water in a test-tube, and then cork it tightly, while steam is still issuing from its

mouth. Though removed from the fire, the water will continue to boil. This will be best observed by inverting the tube, as the bubbles of steam form more rapidly from the cork surface than from the glass. A few drops of cold water sprinkled on the tube will occasion a more violent



ebullition; while on the other hand, boiling water, or the application of flame, will cause the boiling to cease.

Explain the principle of the culinary paradox. 202. EXPLANATION.—The principle is the same as in the experiment of paragraph 200. As the steam condenses, by the cooling influence of the air, a partial vacuum is produced, with diminished pressure, which enables the water to boil with less heat. Cold water, by condensing the steam and removing the pressure more perfectly, increases the ebullition, while boiling water or flame renews the steam, and consequent pressure, and therefore checks boiling.

Describe the "Water Hammer." 203. WATER HAMMER.—The test-tube prepared as above, is a simple form of the "water hammer." If very thoroughly cooled, and then shaken with the kind of motion which would be required to make a bullet rise half way in the tube and fall again, the water will strike like lead on the bottom. It is because there is no air and but little vapor present to break its fall.

How may syrup be boiled below 212°F.? 204. SUGAR BOILING.—When syrup is boiled down under the ordinary pressure of the atmosphere, it is apt to be browned or injured in flavor. By boiling it in a pan with an air-tight lid, and pumping off the air, and the vapor as fast as formed, boiling may be easily effected at a temperature as low as 150°. This method is put in practice by sugar boilers, and the disadvantages above mentioned are thus avoided.

Can food be cooked by the same method?

205. In cooking, this method could not be employed. The water might, indeed be made to boil at 180° , but the boiling water, owing to its less heat, would not have the effect of water boiling at 212° . Many vegetable juices and infusions which are used for medicines, and would be injured by a high temperature, are boiled down, like sugar syrup, under diminished pressure.

Explain the singing of the tea-kettle.

206. SINGING OF THE TEA-KETTLE.—

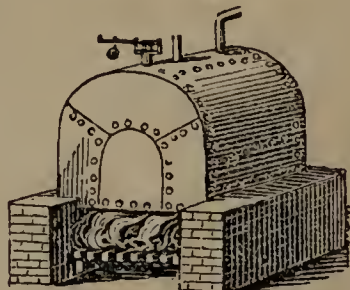
The singing sound which precedes boiling, is owing to the collapse of the first bubbles of steam, as they rise into the colder water above. The very first bubbles that form are not steam, but air which the heat expels. Steam bubbles are then formed, which rise a little way, and, being reconverted into water, contract, and finally collapse. If the heat is continued and the water made hotter, the next are able to rise further. Finally, when the water becomes as hot as the bubbles, they make their way through, and boiling is thus commenced.

What is a steam boiler?

207. STEAM BOILERS.—The boiler is the vessel in which steam is formed. From the boiler it passes to other parts of the apparatus to move the machinery. Steam boilers are of various forms, but are always made of great strength, to resist the internal pressure to which they are subjected.

Explain the figure.

208. The figure represents an ordinary steam boiler, with



the pipe which conveys the steam to the engine. A safety-valve is also represented, which will be more fully explained in another paragraph.

How great is the elastic force of steam? 209. ELASTIC FORCE OF STEAM.—Under ordinary circumstances, the elastic force of steam is obviously equal to the elastic force or pressure of the atmosphere. A man who rises from a chair with a fifty-six pound weight on his shoulder, must exert an extra muscular force, equivalent to fifty-six pounds, in rising; and he must continue to exert it while he stands. So every bubble of steam must have an elastic force equal to that of the air which it lifts, or it cannot be formed under the pressure of the atmosphere, or continue to exist when once formed.

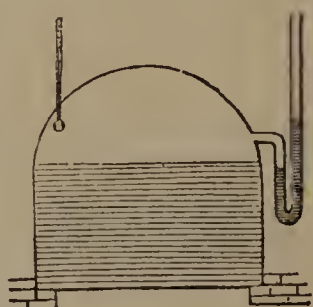
How is the elastic force of steam increased? 210. ELASTIC FORCE, HOW INCREASED. As long as the vessel, in which steam is made, is open, the pressure is as stated in the last paragraph. But if the boiler is closed steam-tight, and the heat continued, more steam forms, and, crowding into the same space above the water increases the pressure. In other words, the space becomes filled with denser steam, of greater elastic force; and the force is finally sufficient to burst the boiler, unless it can find some vent.

What accompanies increased pressure of steam? 211. INCREASED TEMPERATURE ACCOMPANIES INCREASED PRESSURE.—Steam of high elastic force can only be made in a close vessel. But in proportion to the increase of elastic force, is the increase of pressure on the surface of the water. Therefore, the boiling point becomes higher and higher, or, in other words, the wa-

ter has to grow constantly hotter, in order that steam may form ; and as steam always has the temperature of the water with which it is in contact, the steam grows constantly hotter also.

How can the exact relations of temperature to pressure be determined?

212. THE EXACT RELATION OF TEMPERATURE TO PRESSURE.—It is desirable to know the increase of pressure for each elevation of temperature. A steam boiler supplied with a barometer gauge and a thermometer affords the means of ascertaining this relation. Or it may be done by a very small boiler, made for the purpose. The barometer gauge is nothing more than a bent tube fitted into the boiler, open to the air at the top, and containing quicksilver in the lower part of the bend. We will suppose all the air to have been expelled from the boiler, the stop-cock through which it made its escape closed, and the whole interior to be filled with steam. As more steam is produced, pressure is increased, and the temperature of both water and steam rise, as before explained.



What pressure has steam at 250°? at 275°? at 294°? How is this shown?

213. Where the temperature has reached 250°, it is found that the pressure of the steam, acting on the surface of the quicksilver, is sufficient to force and hold the latter thirty inches higher in one arm of the tube than in the other. But the steam with which the boiler was filled when the stop-cock was closed, exerted a pressure of fifteen pounds per square inch, just sufficient to balance the pressure of the external air, and

prevent its forcing the quicksilver before it and crowding into the boiler through the tube. As before stated, when the thermometer reaches 250° , it is found that the denser steam will not only balance the atmosphere, but has force enough to lift the mercury thirty inches, which is equivalent to another atmosphere. Steam at 250° , and in contact with water, is therefore said to exert a pressure of two atmospheres, or thirty pounds to the square inch. At 275° it has a pressure of three atmospheres; and at 294° , of four.

*What is said
of the elastic
force of vapors
at low tem-
peratures?*

214. [ALL VAPOR HAS ELASTIC FORCE.

The apparatus just described shows the pressure of steam at and above 212° degrees.

But vapor of water has elastic force at all temperatures. This is best shown by passing a little water up into a Toricellian vacuum, and observing the effect. The water is introduced by blowing it through a glass tube, one end of which is brought under the mouth of the inverted tube. The drop rises and floats on the mercury, and as vapor forms at all temperatures, a portion of it is immediately converted into vapor. At the same time the level of the mercury is depressed. It is crowded down in opposition to the pressure of the air outside, by the elastic force of the vapor formed. For the sake of simplicity, the space above the mercury was supposed to be a vacuum, but the effect is the same as if it is filled with air. For, as has been already shown, vapor is produced as well in air as a vacuum, and with the same elastic force. If the top of the tube is warmed, denser vapor is formed



possessing greater elastic force, and the mercury sinks lower, till at 212° the elastic force within, is equivalent to the pressure of the atmosphere without, and the mercury is pressed down to the external level.]

Explain the construction and use of the barometer-gauge.

215. BAROMETER-GAUGE.—The principle of the barometer-gauge has already been explained. A few words will be added here as to its use and construction. It is always desirable to know the pressure in a steam boiler, as an evidence of safety, and in order that the fires may be regulated accordingly, and no more fuel be consumed than is necessary. Sometimes the tube containing the quicksilver is of glass, and then the height of the mercury can be seen. In other cases it is made of iron, and the change of level of the quicksilver is indicated by a float.

Explain the thermometer-gauge.

216. OTHER STEAM GAUGES.—A thermometer may be made to answer, perfectly, the purpose of a steam gauge, as is evident from what has been said in paragraph 213. The advantage of such a gauge is, that it takes but little room; its disadvantage, that it is liable to be broken.

Explain the principle of another gauge.

217. There is still another kind of gauge, in which the force of the steam operates on a metallic spring, which moves an index more or less, according to the pressure. The spring gauge is commonly used in locomotive boilers.

Explain the difference between high and low pressure engines.

218. ACTUAL PRESSURE IN DIFFERENT ENGINES.—The actual pressure of steam, used in different forms of the steam engine, varies very widely. There are low

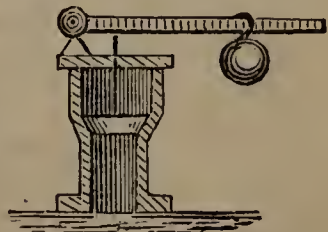
and high pressure engines. In the former, steam of ten to thirty pounds effective pressure is used ; in the latter, the pressure often reaches, and sometimes exceeds, seventy-five pounds. To measure the pressure, the steam guage described in paragraph 215 would have to be five or six feet long. It is on account of this inconvenient length, that other gauges are often substituted.

*What is meant
by effective
pressure?*

219. By effective pressure, is meant the surplus over and above that which is necessary to counterbalance the pressure of the atmosphere, or that of the uncondensed steam, on the opposite side of the piston.

*Explain and
illustrate the
principle of
the safety
valve.*

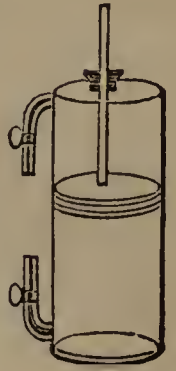
220. SAFETY-VALVE.—The safety-valve is a contrivance, by means of which the steam finds vent through a hole in the boiler, whenever its force becomes too great for safety. A piece of metal shaped somewhat like a decanter stopper, fits into the hole above mentioned, and is loaded by a weight, which can be made greater or less at pleasure. As long as the steam has not too great pressure, the stopper continues in its place, and the boiler is as tight as if it had no such opening. When this pressure is exceeded, the valve is lifted, and steam escapes. The stopper, being loaded, falls back again, as soon as the pressure is relieved.



*Explain the
principle of
the steam en-
gine.*

221. THE STEAM ENGINE.—The power applied in the steam engine is the elastic force of steam. The figure represents a cylinder and close fitting piston, and tubes

through which steam may be admitted at pleasure, either above or below. When the valve in the lower tube is opened, the steam under pressure in the boiler, expands and enters the cylinder, lifting the piston. If the steam is next admitted above, it drives the piston back again, and the latter may thus be kept in constant motion, and made to move wheels, shafts, or other machinery. It is only necessary, that whenever steam enters, that which is on the other side of the piston shall find its way out, into the air. Valves are provided for this purpose, which are opened and closed, at the right time, by the machinery which the piston itself moves.



What is a high pressure engine?

222. HIGH PRESSURE ENGINE.—The engine, here described, is called the high pressure engine. The steam which moves it, must evidently have elastic force greater than that of the atmosphere, or it cannot expand and drive out the waste steam, in opposition to the elastic force of the air. Steam of much higher pressure is used in such engines, than in those to be next described, and hence their name.

Explain the principle of the low pressure engine.

223. LOW PRESSURE ENGINE.—The same figure will answer to illustrate the low pressure engine. The difference is, that the steam which has been used is not driven out, but disposed of, on the spot, by converting it into water. The advantage of this will be readily perceived. Suppose the space above the piston to be full of steam. A jet of water is made to

play into it and condense the steam, and thereby produce a vacuum. When, immediately afterward, steam is admitted below the piston, the latter has nothing on the other side to drive out, and consequently rises more easily. As less force is required, steam of lower pressure may be used, with a corresponding economy of heat and the fuel required in its production.

What is the use and object of the condenser? 224. THE CONDENSER.—In steam engines, as now made, the water used to condense the steam, does not come into the cylinder itself, but into a side vessel, called the condenser. The steam expands into this vessel, and is condensed, producing a vacuum in the cylinder itself, as effectually as if the water were there introduced. The object of the modification is to avoid cooling the cylinder, and thereby diminish the effect of the steam subsequently entering from the boiler. This engine is called the low pressure engine, from the fact that steam of lower pressure may be employed to move it than is the case with the engine previously described. It may, indeed, be made to run with vapor formed below 212° , instead of steam. But in practice, steam of from ten to thirty pounds effective pressure is employed.

Explain the original low pressure engine. 225. ORIGINAL STEAM ENGINE.—In the original form of the steam engine, the pressure of the atmosphere, instead of steam, was applied on one side of the piston, and it therefore received the name of the atmospheric engine. Suppose the cylinder in the last figure to be open at the top, and the piston at its full height. On condens-

ing the steam below it, the piston would evidently sink, in consequence of the pressure of the atmosphere. By thus employing steam pressure on one side, and atmospheric pressure on the other, a constant motion would be realized. But the effective power would evidently be less than in the low pressure engine, because part it would have to be expended each time in lifting the piston, in opposition to the pressure of the atmosphere.

Explain the figure.

226. A test-tube provided with a piston made of cork, or better of wood wound with cotton, suffices perfectly to illustrate the source of power in the steam engine. On boiling a little water in the tube, the piston rises. On dipping it into cool water, and thus condensing the steam, the piston is forced down to the bottom, as in the original form of the low pressure engine. In the ascent of the piston, the analogy is not perfect; for it is, in this case, the production of new steam, and not, as in the steam engine, the expansion of steam already produced, that causes the piston to ascend.



Explain the action of steam in the engine cylinder.

227. STEAM USED EXPANSIVELY.—It is not necessary in the steam engine, that steam be made to flow from the boiler during the whole movement of the piston, from one end of the cylinder to the other. When the cylinder is partly filled, the supply is cut off, and the steam already introduced drives the piston through the

remainder of the distance, by its own expansive force. By this arrangement, instead of using a cylinder full of steam at each movement of the piston, only one-fourth, or even less, according to its density, suffices. Steam employed in this manner is said to be used *expansively*. The term is applied especially to this case, although it is a fact that steam always acts expansively.

228. CONVERSION OF VAPORS INTO LI-

*How are va-
pors converted
into liquids?
Example.*

QUIDS.—If a vapor, in any way, loses its latent heat, it at once becomes liquid. If,

for example, steam be led into a cool pipe, the metal abstracts the latent heat, and the steam becomes water. At the same time, the heated pipe imparts warmth to the air around it.

229. HEATING HOUSES BY STEAM.—

*How are
houses heated
by steam?*

Houses are thus heated, by steam pipes passing through the various apartments.

The pipes abstract the heat, and give it out again to the air of the house. The steam thus converted into water, runs back into the boiler to be reheated, and to start again on its journey. And as long as heat is supplied, the water continues its service as a carrier of heat.

230. WATER HEATED BY STEAM.—When

*How is water
heated by
steam?*

steam is led into water, the effect is the same as on leading it into a cold pipe.

The water abstracts its latent heat, and becomes hot, while the steam itself becomes additional hot water. Water in different parts of a room, or even of a large manufacturing establishment, may thus be made to

boil by one fire ; steam being led into it, by long pipes, from a single boiler.

Prove that boiling is effected by latent heat.

231. PROOF THAT BOILING IS EFFECTED BY LATENT HEAT.—No amount of boiling water, if poured into cold water, will make it boil. But steam no hotter than the boiling water, if led into cold water, will have this effect. Now, as both the hot water and the steam were the same in respect to sensible heat, if the steam effects what the water does not, it is evident that it must do it by hidden, or latent heat. It is only latent heat which the steam loses, for it becomes itself converted into equally hot water.

How much latent heat does steam contain?

232. QUANTITY OF LATENT HEAT.—A pint of water will make enough steam to fill a globe nearly four feet in diameter. If this amount of steam could suddenly become a pint of water, and be prevented from flying off into steam again, it would become red hot. The latent heat of the steam would have raised the temperature from 212° to 1212° —a thousand degrees. Steam is therefore said to contain 1000 degrees of latent heat. *Vide App.*

What is the relation of sensible to latent heat?

233. SUM OF SENSIBLE AND LATENT HEAT ALWAYS THE SAME.—Vapor formed by the heat of summer, occupies more space, and contains more heat, in a latent condition, than is contained in steam. And it is found to be a universal fact that, just in proportion as vapor or steam *feels* cool, or indicates a lower temperature to the thermometer, it contains more latent heat to the same quantity of water. The sum of the sensible and latent heat is always the same—about 1200° degrees.

Why is there no economy in evaporating at low temperatures?

234. **ECONOMY IN EVAPORATION.**—It follows that evaporation at low temperatures, such as is practiced sometimes in sugar-houses, has no advantage of economy.

The vapor that passes off, carries with it less sensible heat, but enough more latent heat in proportion, to make up the difference.

Describe the process of distillation.

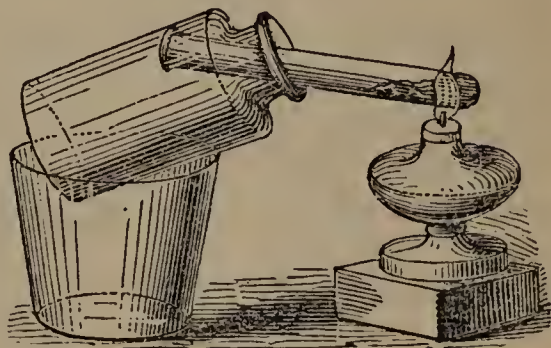
235. **DISTILLATION.**—Distillation consists in converting a liquid into vapor, and recondensing the vapor. The apparatus

represented in the figure, suffices for illustration.

Water being boiled in the test-tube, the steam condenses in the cooler vial.

If the latter is covered with wet paper, the condensation is more perfect.

The apparatus commonly used in distillation, consisting of retort and receiver, is represented in the appendix.



What is the object of distillation? Give examples.

236. **OBJECT OF DISTILLATION.**—The object of distillation is commonly to purify, or, in other words, to separate the liquid distilled, from other substances with which

it may be mixed. Thus, sea water is distilled to separate the pure water from salt. The water becomes steam, and is condensed as pure water, while the salt remains behind. So alcohol is distilled, or converted into vapor, and recondensed, to separate it from water, and the various refuse matters which are mixed with it after fermentation. But the separation is not per-

fect, for, although alcohol is more volatile, and distils more rapidly, a portion of water always distils with it. Distilled liquors, therefore, uniformly contain a certain proportion of water.

CHAPTER IV.

ELECTRICITY AND MAGNETISM.

What properties has the native magnet?

237. NATIVE MAGNETS.—The native magnet, or loadstone, is a mineral which has the remarkable property of attracting metallic iron to itself, and of taking north and south direction, when suspended and free to move. Particles of iron brought near, rush toward it, and remain attached to its surface, without any visible cause. It exerts this attractive force just as well through wood, stone, or any other material, as through the air.

Describe an artificial magnet.

238. ARTIFICIAL MAGNET.—The same properties may be imparted to a piece of steel, by a process to be hereafter described.

Such a piece of steel thereby becomes itself a magnet. Magnets are often made of a shape approaching that of a horse-shoe, the two poles being brought near to each other. A piece of soft iron, called an armature, is placed across the end to prevent the loss of magnetic power, which is found otherwise to occur.



What is the magnetic needle?

239. MAGNETIC NEEDLE.—If a steel bar be made into a magnet, and then balanced on a pivot, it will turn, until one end points north and the other south. That which moves toward the north is called the north pole, and the other end the south pole. A small bar thus balanced is called a mag-



netic needle, and is the essential part of the mariner's compass.

How do the poles of magnets act on each other?

240. **ATTRACTION OF MAGNETS FOR EACH OTHER.**—The law of attraction between magnets is, that unlike poles attract, and like poles repel. The north pole of one magnet, therefore, attracts, and is attracted by the south pole of another.

Why does the magnetic needle point north?

241. **WHY THE MAGNETIC NEEDLE POINTS NORTH.**—The tendency of the north pole of the magnetic needle to turn north, and the other pole south, may be accounted for by the supposition of an enormous magnet running through the earth, with powerfully attracting poles in each hemisphere. In order that the pole of the supposed magnet in the northern hemisphere may attract the north pole of the magnetic needle, we must suppose it to be a south pole, and for a similar reason we must suppose the pole in the southern hemisphere a north pole. Or this inconsistency may be avoided, and the poles of the supposed terrestrial magnet named according to their geographical position, if we regard what is called the north pole of the needle, as endowed with austral or southern magnetism, and the south pole with northern or boreal magnetism. This view is, in fact, adopted in all writings on magnetism. The received theory is hereafter given.

Explain induction of magnetism in soft iron.

242. **INDUCED MAGNETISM.**—When a piece of iron is brought near to a magnet, the iron receives magnetism, by induction, and becomes itself, temporarily, a magnet. If approached to the south pole, its adjacent end ac-

quires north, and the remote one south polarity, and mutual attraction results. By virtue of its acquired or induced magnetism, it will attract another piece of iron, as is represented in the figure, and affect it in all respects similarly. From the second key, another smaller one may be suspended, and from this another, and so on. It is only necessary, that each successive object shall be smaller than the one to which it is attached. The magnetism thus acquired is only temporary in the case of iron, but in the case of steel it is in some degree permanent, and may, by the proper means, be rendered entirely so.



*What is said
of diamagnet-
ism?*

243. DIAMAGNETISM.—If a needle of iron be hung, by a thread, between the poles of a horse-shoe magnet, it immediately turns, so that one of its ends points to the north pole, and the other to the south. This is also a consequence of induced magnetism, as explained in the preceding paragraph. The metal nickel, oxygen gas, and many other substances, both solid, liquid, and gaseous, are similarly attracted by the poles of a magnet, though in a much less degree. All bodies which are not attracted are repelled, and if suspended between the poles, turn so as to bring their extremities as far away from the poles as is possible. The former class are called magnetic, and the latter *diamagnetic* bodies. To show the phenomena of attraction and repulsion with gases and liquids, the materials are inclosed in tubes or bulbs. In the case of most substances, excepting iron, these effects can only be at-

tained by means of powerful magnets and delicate apparatus.

ELECTRICITY.

What is frictional electricity? 244. FRICTIONAL ELECTRICITY.—If a glass tube is rubbed with silk, it will afterward attract to itself filaments of the silk, as a magnet attracts iron. Or, if the knuckle be approached to the tube, a spark may be drawn from it. These phenomena are called electrical. Both glass and silk are said to be electrically excited. The same experiment may be made with a stick of sealing-wax.

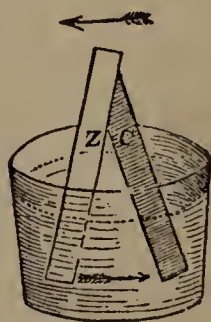
State the theory of electricity. 245. THEORY OF ELECTRICITY.—According to the view commonly entertained of these phenomena, both glass and silk contain two electrical fluids in a state of combination, which are so separated by friction, that the positive fluid of both accumulates in the glass, and the negative in the silk. The positive sustains the same relation to the negative, that the north polarity of a magnet does to the south; and, in consequence of the difference of the separated fluids, the two bodies containing them attract like opposite poles of a magnet. It is also true, that similarly electrified bodies repel like similar poles of magnets. As in the case of heat and light, we know nothing of the electrical fluid, save by its effects.

Illustrate by examples. 246. The human body may also be electrically excited, so as to yield a spark, by rapid sliding over a carpet. Gas may be lighted by the spark. The gas in certain manufactories is instantane-

ously lighted throughout the whole establishment by electricity developed by the friction of the machinery.

Explain the conduction of electricity. 247. CONDUCTION OF ELECTRICITY.—Like heat or caloric, electricity may be conducted from one body to another. Thus, if a piece of metal be electrically excited, or, in other words, charged with a quantity of either the positive or negative fluid, another piece of metal will immediately become so on connecting it with the first by a metallic wire. The connection being formed, it will attract or repel filaments of silk or other material, precisely as the first one does. The fluid is supposed to flow from one piece of metal to the other, through the wire, and we therefore speak of a current of electricity. But it is not certain that any thing actually passes, any more than in the case of light and heat before considered.

What is galvanic electricity? 248. GALVANIC ELECTRICITY.—It is also found that electricity is developed when two metals are placed in contact with each other, and with an acid at the same time, as is represented in the figure. The metals must be such that the acid will act on one of them. Zinc and copper being used the former is dissolved, and the current flows continuously in the direction indicated by the arrows. This apparatus is the simplest form of the galvanic battery.



What is an electrode? 249. ELECTRODES.—For convenience in certain experiments, it is customary to attach platinum wires, to the exterior portions of the metallic slips. These are called electrodes. The wire con-

nected with the copper forms the positive electrode, and the one attached to the zinc, the negative.

Why is platinum used for electrodes?

250. Platinum wire is chosen, because there is frequent occasion to immerse the electrodes in corrosive liquids, and this metal, for the most part, withstands their action. For many experiments, it is found best to flatten the ends of the wires forming the electrodes, so as to produce a larger surface. The same object may also be effected by terminating them with strips of platinum.

What is the electrical condition of atoms?

251. ELECTRICAL CONDITION OF ATOMS. All atoms of matter are regarded as originally charged with either positive or negative electricity. Hydrogen and the metals are electro-positive; oxygen, chlorine, and cyanogen, and other substances, to be described hereafter, are negative. A molecule of water is made up of a positive atom of hydrogen, and a negative atom of oxygen; hydrochloric acid, of positive hydrogen and negative chlorine; oxide of silver, of positive silver and negative oxygen. The figure, in which + represents positive and — negative, may represent a molecule of either of the compounds named.

What quantity of electricity is contained in water?

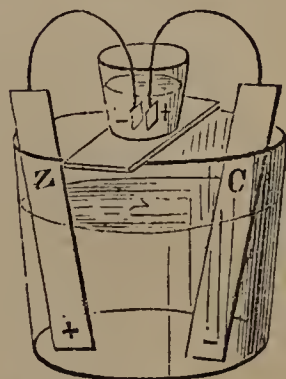
252. QUANTITY OF ELECTRICITY.—The quantity of electricity thus combined or neutralized, in almost all kinds of matter, is enormous. Faraday has stated that a drop of water, contains more than is discharged in the most violent flash of lightning.*

The terms *atom*, and *molecule*, are synonymous. But “molecule” is limited, in the present work, to the particle of a compound.

* This opinion has been recently declared erroneous.

Describe the decomposition of water.

253. DECOMPOSITION OF WATER.—If the electrodes are immersed in water, as represented in the figure, the water is decomposed, and separated into its elements. Bubbles of hydrogen collect on the negative electrode, and bubbles of oxygen on the positive, and finally disengage themselves, and rise through the water.

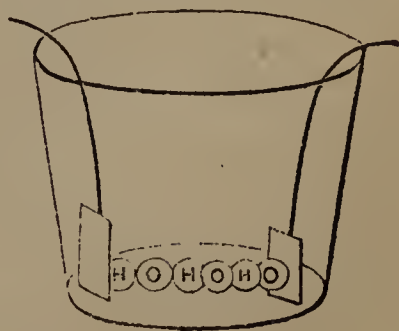


Why does hydrogen appear at the negative pole?

254. It is to be observed that *positive* hydrogen is liberated at the *negative* pole, as if the latter had a power analogous to that of the magnet for iron, to draw the hydrogen out of the water, in which it exists combined. On the other hand, negative oxygen is liberated at the positive pole, as though the latter had the same attractive power for oxygen. The above figure is given solely for the purpose of illustration. The actual form of apparatus for decomposing water, by the galvanic current, is described in a subsequent paragraph.

Give the theory of the decomposition of water.

255. THEORY OF THE DECOMPOSITION OF WATER.—It is a remarkable circumstance, in the decomposition just described, that it continues to occur even when the electrodes are quite widely separated from each other. Now, a molecule of water is extremely small, and cannot occupy the space between the electrodes, if they are separated to any considerable extent. The space must be occupied by many such particles, which,



for the sake of definiteness, we will conceive of as arranged in straight lines, between the two electrodes. The circles in the figure, inscribed H and O, represent one of these lines of molecules. The difficulty now arises, to account for the fact, that when the hydrogen is liberated at the negative pole, the oxygen, combined with it a moment before, is not also liberated at the same point. The view to be taken of it is as follows: that as soon as the atom of oxygen loses its hydrogen, it combines with the hydrogen of the next molecule of water. The oxygen of this second one being thereby liberated, combines with the hydrogen of the next; and this decomposition and recombination continues throughout the series. The end of the series being reached, the last oxygen atom escapes in the form of gas. The action being simultaneous throughout the series, this evolution occurs at the instant that the hydrogen is set at liberty at the negative electrode. It is, therefore, quite as proper to give the explanation of the difficulty first stated, by beginning with the liberation of oxygen at the positive electrode. We then suppose the hydrogen to combine with the oxygen of the next molecule of water in the series, and so on to the negative electrode, where hydrogen is evolved. The action is, in fact, as before stated, simultaneous.

Explain the deposition of metals by galvanism.

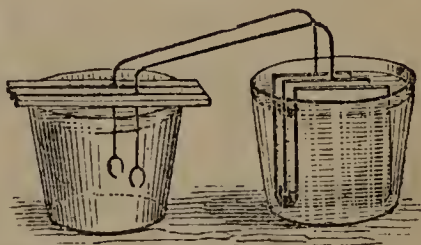
256. DEPOSITION OF METALS.—The metals are electro-positive. Oxygen, chlorine &c., on the other hand, are negative. If therefore, oxides, chlorides, or cyanides of the metals are subjected to the action of the electrodes, they are decomposed, while the metal

goes to the negative, and the oxygen, chlorine, or cyanogen, to the positive. But the metals, when separated from their combinations, being solid bodies, cannot escape. They collect on the negative electrode, instead. If this be attached to a brass spoon or fork, or any other object it is desired to plate, the spoon becomes itself the electrode, and the metal is deposited upon it as long as the action of the battery continues. At the same time, the oxygen, or other negative element, goes to the positive electrode, generally corroding it, instead of passing off as gas.

What apparatus is required for electro-silvering?

257. SILVERING APPARATUS.—The requirements for electro-silvering or gilding, are first, a battery of somewhat different form from that already described, though precisely the same in principle; second, an acid to excite it; and third, a solution containing gold or silver. These will be described in turn.

258. A convenient form of the apparatus is represented in the figure, and may be prepared from sheet zinc and copper in a few moments. It consists of a bent strip



Explain the figure.

of the former metal, with a strip of copper fastened between the two portions. The metals should be within an eighth of an inch of each other, but without contact. To secure this, they are tied together with thread, bits of wood or cotton cloth being previously interposed. Copper wires being attached to the zinc and copper, as represented in the figure, the apparatus is placed in a common tumbler, and the battery is complete.

*How and why
is the zinc
coated with
quicksilver?*

259. Before combining the battery as above described, it is best to wash the zinc with soap and water, and afterward with dilute sulphuric acid, and then to immerse it for half a minute or so in a solution of nitrate of mercury. By this process, the zinc acquires a thin film of quicksilver, which afterward protects it from the action of the acid used to excite the battery, excepting when the circuit is completed. When the battery is in operation, it also has the effect of making the action, more equal and constant. It is then to be again washed, and newly immersed in the acid solution. This solution is prepared by dissolving quicksilver, of the bulk of two peas, in nitric acid, and pouring the clear liquid into a tumbler of water.

*How is the ex-
citing acid
prepared?*

260. THE EXCITING ACID.—The exciting liquid is dilute sulphuric acid, consisting of one part oil of vitriol, to ten parts of water. The acid is mixed with the proper quantity of water, and set aside to cool.

*How is the sil-
vering solution
prepared?*

261. THE SILVERING SOLUTION.—To make a half pint of the solution, a dime is placed in a test-tube and dissolved in nitric acid, the solution being diluted with water. Muriatic acid is then added, which precipitates the silver, in the form of a white curd. This is allowed to settle, and the green liquid, which contains the copper of the coin, is poured off. Water is again added, and the curd allowed to settle; this cleansing process is several times repeated. The test-tube is then half filled with water, and heated, and bits of cyanide of potassium added, until a transparent solution is obtained.

How is the solution for gilding prepared?

262. A solution for gilding, is prepared by drying a solution of gold, at a moderate heat, and dissolving it in cyanide of potassium, as above described. The process for gilding, is in all respects the same as that for the deposition of silver.

How is the silvering process conducted?

263. THE PROCESS.—The battery and silvering solution being prepared, the copper coin, or other object to be silvered, is cleansed with potash, rubbed with chalk or rotten-stone, and then attached to the wire proceeding from the zinc. A silver coin is fastened to the other wire, and immersed in the silvering solution; acid is then added to excite the battery, and the object to be silvered is lastly immersed. It should be hung face to face with the silver coin, and quite near to it, the two being kept in their places by blocks placed across the tumbler, as represented in the figure. The coin will receive a perceptible coating within a few minutes, and will be more thickly covered, according to the time of immersion. The deposit is hastened by keeping the solution moderately warm. This is especially advantageous in the commencement of the process. The newly plated surface is without lustre, and requires burnishing after removal from the solution.

What is the object of the silver coin?

264. OBJECT OF THE SILVER COIN.—The piece of silver is attached to the positive wire, to maintain the strength of the solution. It is eaten away, and dissolved as fast as silver is deposited on the objects connected with the negative wire. The reason of this is, that the cyanogen of the

solution, when it goes to the positive pole, as before explained, combines with silver, forming new cyanide of silver, which dissolves and mixes with the rest. Thus, the strength of the solution is always maintained. The coin is attached to the negative wire, by flattening the latter, laying it on the back of the coin, and covering the whole with sealing wax; the coin and wire should be previously slightly warmed, and the wax used at a moderate heat, so that it shall not run between the wire and the coin, and prevent their perfect contact.

How are medals copied?

265. COPYING OF MEDALS.—If it is desired to copy the face of a medal or a coin, the same apparatus suffices. The reverse and edges of the coin are very slightly oiled, to prevent the adhesion of the copy about to be made. It is then placed in the solution. The metal deposits upon it, copying perfectly every elevation and depression. When the crust is sufficiently thick, which will be after the lapse of twelve hours, the coin, with its shell of metal, is removed, and the whole process repeated with the mould. The deposit which now forms in the shell, is an exact copy of the face of the original coin. Moulds are also made by stamping the coin into soft metal, and using the impression thus produced instead of the copper shell. Copper plates, for engravings, may be copied so perfectly by the first method, as to be fully equal to the original.

How are wood cuts copied?

266. COPYING OF WOOD CUTS.—The difficulty of copying other than metallic objects, by the process, is, that they are not generally good conductors. Thus, when a wood cut is attached to the negative wire, it does not itself receive a nega-

tive character from the wire, and will not, therefore, take positive metal from the solution. This is obviated by covering the block with a fine powder of plumbago or black lead, which has good conducting power.

*It what cases
is the process
practised?*

267. This process is very extensively practised. Where a large number of cuts of the same kind are wanted, as for example, to print labels for dry goods, only one engraving on wood is made, and numerous copies are taken by the above process, which is much less costly.

*Describe the
heating effect
of the current?*

268. HEATING EFFECTS OF THE CURRENT.—If the electrodes are connected while the battery is in action, the wire becomes heated more or less strongly, according to the size of the plates. If the plates are very large, the wire melts, even though it be of platinum, the most infusible of metals. Gold may even be converted into vapor by the same means. Carbon, supposed a few years since to be entirely infusible, may be also superficially fused, and even volatilized between the electrodes. It condenses again at a little distance, in the form of microscopic crystals. Imperfect diamonds have been thus artificially produced. With such a battery as has been described the elevation of temperature would be scarcely perceptible.

*How is the
electric light
produced?*

269. THE ELECTRIC LIGHT.—If the current be allowed to pass between two points of prepared charcoal, an exceedingly intense light is produced, accompanied by great heat. Charcoal is employed because it is a comparatively infusible, and inferior in conducting power. A metallic

wire, under the same circumstances, would melt, or if too large to undergo fusion, would allow the current to flow readily through it, without that detention which is essential to the production of the above effects, in their highest degree.

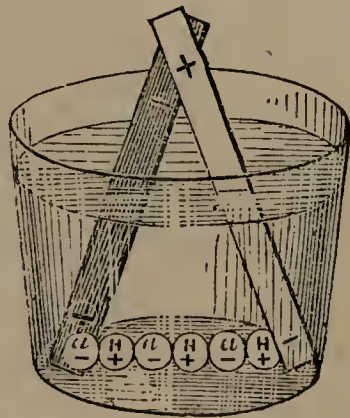
How is the electric flame produced?

270. If the charcoal points be withdrawn from each other, a splendid electric flame is produced between them. This flame is not the result of combustion, for the charcoal is extremely dense, and wastes away but slowly. It is purely electric. Metals melt in it, and are dissipated in vapor. A much larger battery than that just described, is requisite for the production of either the light or flame. In experimenting with the compound battery, hereafter described, a slight spark will be observed, on separating the electrodes.

What is the cause of the galvanic current? Explain the chemical action.

271. SOURCE OF GALVANIC POWER.—The exciting cause of the galvanic current is found in the chemical action which occurs in the battery. This action is analagous to that described in § 255. Suppose, for example, the acid with which the zinc and copper are in contact, to be hydrochloric, each molecule of which is composed of an atom of hydrogen and an atom of chlorine. The zinc becomes positive where it is in contact with the acid, and negative at the other end, the extremities assuming different states, as in the case of a piece of soft iron suspended from a magnet. The outer portion of the copper being in contact with the negative end of the zinc, is, itself, negative, while the end immersed is positive. The atoms

composing the acid, are supposed to be arranged as represented in the figure. The alternation of positive and negative, in copper, zinc, and the line of acid molecules is analogous to the case of the suspended keys. As long as the metals are immersed, and made to touch, an atom of zinc constantly combines with an adjacent atom of chlorine. It follows, that no chlorine is set at liberty. As fast as each atom unites with the zinc, its hydrogen combines with the next chlorine, the hydrogen of this, with the next, and so on, as before explained, in the decomposition of water. Hydrogen is therefore constantly given off at the surface of the copper. But when the two metals are not in contact above the liquid, and the circuit is, consequently, not completed, there is no negative influence exerted at the extremity of the copper, and the series of decompositions, before described, does not occur.



Explain how a battery can be excited by a salt?

272. A SALT EMPLOYED AS EXCITANT.—

It is not essential, that an acid shall be used as the exciting liquid in the galvanic battery.

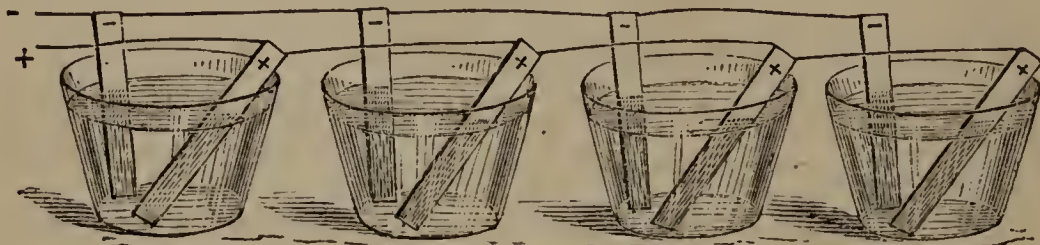
A metallic salt is sometimes employed. This may be best illustrated, by supposing chloride of copper to be employed instead of hydrochloric acid, which is chloride of hydrogen. The chlorine goes to the zinc, as in the previous case, and the copper of the salt, to the strip of copper, placed in the solution. Being a solid, it remains there, and encrusts the copper, instead of being evolved, as in the case of hydrogen.

*What is said
of the differ-
ent kinds of
batteries?*

273. DIFFERENT KINDS OF BATTERIES.—

There are different kinds of galvanic batteries, but the principle in all is the same.

Two of the forms in most common use are described in the Appendix. Smee's battery is especially recommended to the student, for its cheapness, simplicity, and efficiency. It is very similar, as will be seen, to the simple one which has been already described.



*What is said
of the com-
pound circuit?*

274. COMPOUND CIRCUIT.—

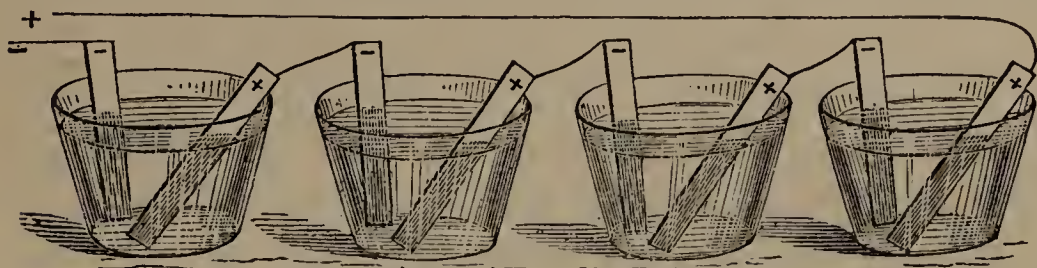
For the sake of simplicity, all the foregoing decompositions have been described, as a result of the action of a simple voltaic circle, consisting of an acid, and two metals. But, it is found that in many decompositions, the power of such a battery is insufficient. The efficiency is increased by employing several single batteries together, and bringing them all to bear upon the same electrode.

*How are heat-
ing and mag-
netic effects
produced?*

275. The heating and magnetic effects

of the battery are very much increased by uniting the plates, as in the preceding figure, where all the zinc plates are joined together, so as virtually to form one. The *quantity* of the current is thus increased. Power of decomposition, and to give shocks, such as are taken from an electrical machine,

are increased by uniting them as in the figure which follows. The *intensity* of the current is thus increased.

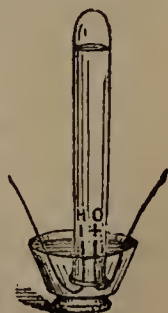


What is the meaning of intensity? Of quantity?

276. MEANING OF INTENSITY AND QUANTITY.—The terms intensity and quantity are rather vaguely used, and do not describe as definitely as may be desired, the different properties of the current. The student must associate the term *quantity* with increased heating and magnetic effects, and the term *intensity*, with power of decomposition.

Explain the apparatus for decomposition of water.

277. DECOMPOSITION BY THE COMPOUND CIRCUIT.—For the decomposition of water, a series of six cups, such as have been already described for use in plating, will suffice. They are to be united according to the second arrangement. The zinc of each cup is to be connected with the copper of the next in order, by a copper wire, forming a good metallic contact. This being done, another long wire is fastened to the first copper plate, and one, also, to the last zinc, and bits of platinum wire or foil are attached to their ends. A small test-tube is then filled with acidulated water, and inverted in a cup, also containing water and acid. The wires are bent upward into the cup, as represented in the figure. The battery being now set in operation, by dilute acid, as before described,



the evolution of gas immediately commences from the the platinum wires. This compound battery will be found rather slow in its operation, and has been described only for the purpose of illustrating the use of the more powerful galvanic batteries of similar construction. The student is advised to substitute for it the Voltaic pile, hereafter described.

What property has the mixture thus produced?

278. AN EXPLOSIVE MIXTURE.—A mixture of hydrogen and oxygen gases, in the proportion in which they are here evolved, is explosive. This property is one evidence that the mixture actually consists of oxygen and hydrogen. A sufficient quantity being collected, the mouth of the tube is covered with the finger, the tube inverted, and a match applied at the mouth. A slight puff is all the evidence that will be obtained from a small quantity of the mixture. A test-tube full will give a sharp report.

How may the gases be collected separately?

279. SEPARATE COLLECTION OF THE GASES.—By using two test-tubes, instead of one, as before described, and introducing an electrode into each, the gases may be separately collected and tested by the methods given in the section which treats of those gases.

Why is the water to be decomposed acidulated?

280. The water is acidulated in the experiment, to make it a better conductor of the influence which must pass through it, from one electrode to the other, in order that the decomposition may take place. The reason for using platinum electrodes has already been given. In the present case, if the copper wires themselves

were introduced, the negative electrode would appropriate all the oxygen to itself, thereby becoming gradually converted into oxide of copper, which would dissolve, and nothing but hydrogen gas would be obtained.

281. DECOMPOSITION OF A SALT.—The

Describe the decomposition of a salt.

decomposition effected by the galvanic current, may be more strikingly illustrated

by introducing the electrodes into a dilute

solution of sal-ammoniac, previously colored by litmus, or red cabbage.

Chlorine is liberated at the positive pole, and bleaches the solution in its vicinity, while ammonia is evolved with hydrogen, at the negative pole,

and changes the color of the solution from blue to red.

That of the cabbage is changed by the same means, from red to green. By employing a glass box with two

compartments, such as is represented in the figure, the two portions of the liquid may be kept distinct. It is

essential, for reasons that will be understood from the preceding paragraph, that there be an unbroken chain

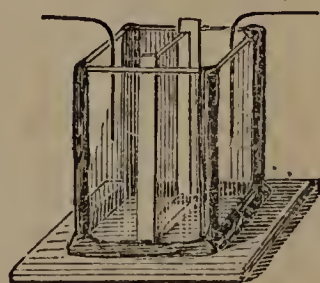
of molecules of the *electrolyte*, or substance to be decomposed, between the electrodes. This is effected by

making the partition quite loose, and keeping it in its place by strips of paper, placed along the edge. All the

communication that is essential, then takes place through the pores of the paper, while the partition at the same

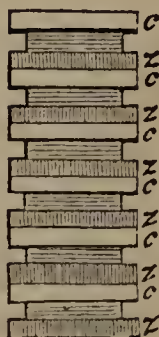
time prevents the mixing of the contents of the separate cells. The same object may be accomplished by

the employment of two tea-cups, holding the liquids, and connected by moistened lamp-wick ; a larger pile,



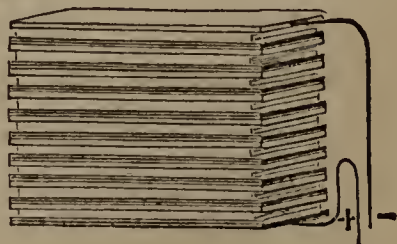
and a longer time, is in this case required to effect the decomposition. The glass box may be made according to the directions given in paragraph 33 for making a prism.

Describe the Voltaic pile. 282. THE VOLTAIC PILE.—The first form of galvanic battery ever produced is represented in the figure, and is called the Voltaic pile, from the name of its inventor. It consists of a succession of discs of zinc, copper, and cloth, moistened with acid, alternating with each other, as represented in the figure. Each series forms a simple battery, and the whole pile is a compound battery, essentially the same as that before described. Wires to serve as electrodes are to be attached to the extreme copper and zinc.



What is said of the enlarged Voltaic pile?

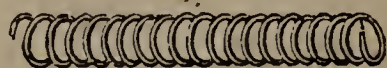
283. The enlarged form of the Voltaic pile represented in the next figure will be found a most efficient apparatus for effecting decomposition. It is composed of sixteen plates of each metal, each having a surface of twelve square inches. The zinc should be amalgamated, as before explained. Flannel, or any similar material may be employed to separate the plates. With this piece of apparatus, the spark is readily obtained, and slight shocks may be taken by bringing the two hands into contact at the same moment with the top and bottom of the pile. On terminating the electrodes with fine iron wire, and frequently uniting and separating them, scintil-



lations of the burning metal may also be readily produced. By increasing the number of the plates still more striking effects are obtained. With a pile consisting of six or eight plates a foot square, platinum wire connecting the electrodes may be readily fused. Such a battery is also more effectual in the electro-magnetic experiments which follow.

Describe the magnetic properties of the galvanic current.

284. **MAGNETIC PROPERTIES OF THE CURRENT.**—If the wire connecting the zinc and copper of the galvanic battery be wound in a spiral, as represented in the figure, the coil, or helix, as it is termed, becomes possessed of magnetic properties. Like a magnet, it attracts iron, and other magnets, and according to the same laws.



How may a rod of iron be suspended in the air?

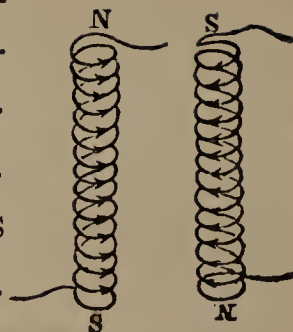
285. **THE SUSPENDED BAR.**—A rod of iron brought near one of the extremities of the coil, is not only attracted, but actually lifted up into the centre of the coil, where it remains suspended without contact, or visible support, as long as the battery continues in action. Science has thus realized the fable of Mahomet's coffin, which was said to have been miraculously suspended in the air. The helix, for this and similar experiments, is wound closer than is represented in the figure, and is composed of several layers of wire. A powerful battery is also essential to success in this experiment.



What is the action of a single wire on magnetic coil?

286. **POLARITY OF THE COIL.**—That such a coil has polarity, may be proved, precisely as with a magnet. One end of it attracts the north pole of a magnet, and

is therefore a south pole. The other end attracts the south pole of a magnetic needle, and is therefore, itself, a north pole. But the direction in which the current moves round in the helix, determines which shall be north, and which south.

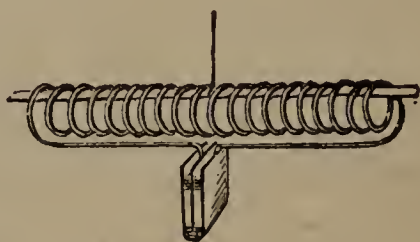


As the current is represented to move in the first of the two coils in the figure, the upper end of the coil is north, and the lower end south. If it is made to move in the other direction, as in the second figure, the poles are reversed.

How may we obtain motion of the coil itself.

287. CONSEQUENT MOTION OF A SUSPENDED COIL.—To obtain motion of the coil itself, as a consequence of its magnetism, it is necessary to suspend it; and in

order to suspend it with perfect freedom of motion, it is necessary to suspend the battery with it. Such a suspended coil and battery is represented in the figure. In preparing it, the wire



is wound forty or fifty times round a test-tube, (which is afterward removed,) and copper and zinc plates then attached to the ends. The plates are tied together with several layers of paper between them, then dipped in acid, and the apparatus carefully suspended by an untwisted silk fibre. The acid absorbed by the paper, suffices to maintain for some time the action of the battery. On approaching a magnet to either pole of the suspended coil, it is attracted or repelled precisely as if it were a magnet. Instead of suspending the apparatus by a thread, it may

be floated on acidulated water, by means of a cork, and submitted to the same experiment. In this construction, the wires proceeding from the end of the coil, pass through the cork, before connecting with the metallic plates. The first described method of suspension is regarded as the best.

288. THE COIL A MAGNETIC NEEDLE.—

How may the coil be converted into a magnetic needle?

On floating a coil with extreme delicacy upon water, and protecting it from all currents of air and water, it assumes north and south direction, and becomes, in fact, a magnetic needle. This can only be accomplished by means of a light glass cup, blown for the especial purpose, and prolonged into a cone below, to give it steadiness in the water. This cup is filled with dilute acid, in which the plates are immersed, and is then floated in a larger vessel.

289. MUTUAL ACTION OF COILS.—

Describe the mutual action of magnetic coils.

Two helices, or coils, such as are described in the last paragraph, floating near each other, attract or repel, precisely as if they were magnets, according as like or unlike poles are brought together. They finally attach themselves to each other in the position represented in the figure, lying parallel and with opposite poles in contact. In this position, it will be observed, that at the point of contact, the currents are moving in the same direction. The attraction of the unlike poles, may be regarded, then, as a consequence of the attraction of like currents. For it is found to be universally true, that



currents moving in the same general direction, attract each other, while those moving in opposite directions, repel.

What is the mutual action of a coil and magnet?

290. MUTUAL ACTION OF COIL AND MAGNET.—If a floating magnet be substituted for one of the coils, in the above experiment, the result is not in the least affected. They act toward each other precisely as if both were magnets, or both, coils.

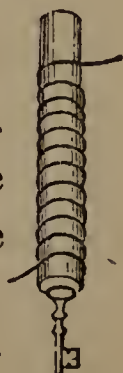
What is the action of single wire on a magnetic coil?

291. ACTION OF A SINGLE WIRE ON A COIL.—A single wire, carrying a current, acts on a floating coil in the same manner. Stretched above it, as indicated in the figure, the north pole of the coil will move to the right. The motion is such as to bring adjacent currents, in the wire, and in the coil, to coincide in direction.



What effect has the magnetic coil upon metals?

292. POLARITY OF THE COIL IMPARTED TO IRON.—A bar of soft iron placed in the coil, becomes itself a magnet, and receives the name of electro-magnet. It should be wound with several layers of continuous wire, the latter being covered with cotton, to prevent any lateral passage of the current. The horse-shoe shape, in which the poles are brought round near to each other, is the more common. The power of such magnets continues only while the current is passing. Electro-magnets have been constructed capable of lifting a ton, or even more. They are sometimes employed in dressing iron ores, to separate, by their attraction, the work-



able ore from the refuse earth with which it is mixed. A steel bar introduced into the helix while the current is passing, becomes permanently magnetic. Permanent magnets, are now commonly made in this manner.

293. PERMANENT MAGNETISM OF STEEL.

What effect has the magnetic coil upon steel?

It appears, from the last paragraph, that a bar of soft iron is a magnet, as long as an electrical current circulates around it.

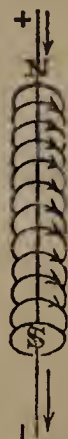
But the steel, if once magnetic, remains so permanently. This is accounted for, by supposing that the current, in the wire, excites a current in the surface of the steel itself, which continues to flow, without interruption, after the wire is removed.

294. ACTION OF A SINGLE WIRE ON

What is the action of a single wire on a magnet?

A MAGNET.—A wire, carrying a current in the direction shown in the figure, acts on a magnet, precisely as

on a floating coil. The north pole of the magnet is made to deviate to the east. The motion is such as to bring adjacent currents in wire and magnet to coincide.



295. ELECTRICAL THEORY OF MAG-

Explain the electrical theory of magnetism?

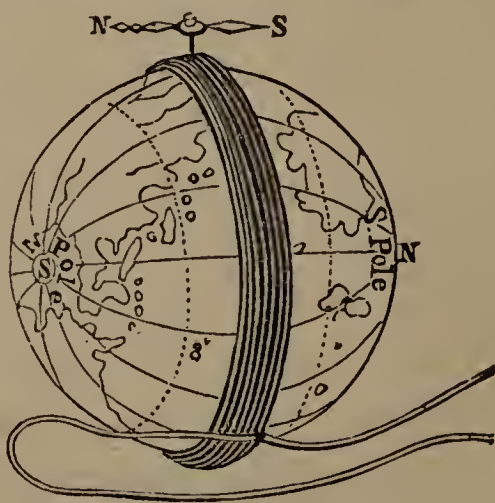
NETISM.—According to this theory, all magnetism, including that of the load-stone, the magnetic needle, and that of the earth

itself, is a consequence of the circulation of electrical currents. In the earth, such currents are known to be excited, and kept in motion, by the sun, heating in turn successive portions of its surface. They flow from east to west, making of the earth, as it were, an immense coil, or helix. In magnets they are also in con-

stant circulation, the direction being dependent on the position in which the magnet is held. In the case of a magnet whose north pole is directed north, the direction is from west to east across the upper surface, and of course, in the contrary direction on the under side. The earth acts on a magnet, or a floating coil, as one helix acts on another. The north and south direction of the magnetic needle is a consequence of this action.

Explain the figure.

296. THE THEORY ILLUSTRATED.—In illustration of this theory, let a globe be coiled with a wire, carrying a current, as indicated in the figure. Let the current flow from east to west through the coil. A small magnetic needle placed at different points on the surface of the globe, however the position of the latter may be changed, will always point to its north pole. It is understood, in this experiment, that the current is strong enough to overcome the influence of the earth itself on the magnet. A freely movable coil through which a current was passing, would, in this case also, act precisely like a magnet.



Explain the principle of the magnetic telegraph.

297. MAGNETIC TELEGRAPH.—The explanation of the mechanism of the magnetic telegraph belongs to Natural Philosophy. The principle of its operation may

be here given. It has already been stated, that a piece of soft iron becomes a magnet, when a current of electricity circulates in a coil surrounding it. Now, suppose the two ends of such a coil, situated in a distant city, to be made long enough to reach a battery in the place where the reader resides, and to be stretched along over posts, and connected with the poles of the battery. The current occupies no perceptible time in its passage. Therefore, as soon as the battery is set in operation, it circulates through the whole extent of the wire, and, of course, through the coil in the distant city. The piece of iron which it incloses is made a magnet, and will immediately lift its armature. If the current is stopped, the piece of iron ceases to be a magnet, and drops its armature. But the operator at the battery can send or stop the current at will, by simply disconnecting one of the wires, and thereby lift or let fall the armature a hundred or a thousand miles off, as often as he pleases. He can have an understanding, also, with the person in the distant city, who sees the motion of the armature, as to what it shall mean. One lift may indicate the letter A ; two lifts, the letter B ; and so on. Words may be similarly spelled out, and it thus becomes possible to communicate ideas by electricity. If these lifts of the armature can be made to record themselves on a slip of paper, the further advantage of writing at the distant station is gained. And this is precisely what is realized in Morse's telegraph, and more particularly described in all recent works on Natural Philosophy.

*What is said
of the earth
as a conduc-
tor ?*

298. THE EARTH, USED AS A CONDUCTOR.

It would seem requisite to extend both ends of the wire forming the coil through all the intervening distance, and then to connect them with the opposite poles of the battery ; but it is found, in practice, that one is sufficient, and that all the middle portion of the second wire may be dispensed with. The remaining ends, one connected with the helix, and the other with the battery, being made to terminate in large plates, and buried in the ground, the earth between them is found to take the place of the second wire, and complete the circuit.

*Mention some
remarkable
applications
of the tele-
graph.*

299. APPLICATIONS OF THE TELEGRAPH.

There are many applications of the telegraph beside the one of transmitting intelligence to distant places. In the city of Boston, an alarm of fire is instantaneously communicated throughout the city, and the bells rung by telegraphic apparatus.

In Marseilles, France, a single clock is made by similar means to indicate the time on dials, placed in the street lamps of the city. Electro-magnetic apparatus has also been employed with the most remarkable success in increasing the dispatch and accuracy of astronomical observations ; making it possible to accomplish during a single night in the study of the heavens, what formerly cost a month of labor.

*Describe the
physiological
effects of gal-
vanism ?*

300. PHYSIOLOGICAL EFFECTS OF GALVANISM.—

The nerves of animals are extremely susceptible to the galvanic influence. The apparatus represented in the

figure, which consists of strips of zinc and copper, three inches in length, separated by a cork, is sufficient to produce convulsive twitchings in the legs of a frog or toad. A



larger apparatus produces more decided effects. The legs are to be employed, with a portion of the back bone attached, which is grasped by the sharpened extremities of the galvanic tweezers. As often as the circuit is completed, by bringing the other extremities into contact, by the pressure of the fingers, the legs are observed to twitch, as if they were still possessed of life. The leg of a grasshopper, held in its thickest part, may also be employed in the experiment. In both these cases, the moisture of the flesh or skin is the exciting fluid of the galvanic pair. In view of the destruction of life which they involve, these experiments should be confined to the lecture room, or only made where many persons are to be instructed by their exhibition.

*How was the
discovery of
galvanism
made?*

301. DISCOVERY OF GALVANISM.—In the words of Arago, “this immortal discovery arose in the most immediate and direct manner, from an indisposition with which a Bolognese lady was affected, in 1790, for which her medical adviser prescribed frog broth.” The frogs had been killed and skinned, and were lying on the table of her husband’s laboratory. Experiments were in progress with an electrical machine, which stood near them, when it was observed that the frogs’ legs were convulsed, as the spark passed. This was not a new fact, but Galvani was not acquainted with it, and un-

dertook to find out the cause. In preparing for the investigation, he chanced to hang the hind legs of several frogs, by copper hooks, from the iron railing of the balcony of his window. As often as the wind, or any accidental cause, brought the muscles into contact with the iron bar, the legs were convulsively agitated. The astonishment of the experimenter can scarcely be conceived. In undertaking to account for an old fact, he had stumbled upon a most important discovery. The theory which he proposed was not correct, but the results to which the observation have since led are astounding. The telegraph, the electrotpe, and many metals discovered by galvanic means, may all be regarded as its offspring.

*Explain the
above experi-
ment.*

302. EXPLANATION.—The convulsion produced in this case, is entirely analagous, in its course, to that described in the last paragraph. The two metals, the moist muscle, and the wind, to produce contact and so complete the circuit, are all the conditions essential to the production of a current, and consequent contraction of the nerves.

PART II.

LAWS OF COMBINATION.

CHAPTER I.

What is the number of the elements? 303. NUMBER OF ELEMENTS.—The number of elements or simple substances at present known is sixty-two. Only thirty-five of these are of sufficient importance to be considered in this work. The rest are of rare occurrence, and are found in comparatively small quantity.

How are the elements subdivided? 304. SUBDIVISION OF THE ELEMENTS. The elements may be divided into metals, and metalloids or non-metallic substances. They are thus divided in the table given on page 131. Hydrogen and oxygen belong to the class of non-metallic substances, but are placed by themselves, for reasons which will appear in the sequel.

Of what are the elementary substances made up? 305. ATOMIC CONSTITUTION.—All of the elementary substances, whether they be solids, liquids, or gases, are regarded as made up of minute atoms, as explained

in Chapter I. All of the atoms of the same substance are alike in every respect.

How does combination take place? 306. COMBINATION BY ATOMS.—When combination takes place between portions of any two elementary substances, it may be regarded as consisting in the attraction and juxtaposition of their individual molecules. Thus, when zinc tarnishes in the air, each of the atoms which form the surface of the zinc, takes to itself an atom of oxygen from the air, and the whole surface becomes covered with molecules of oxide of zinc. In the same manner, sulphuric acid is made up of compound molecules, each one of which consists of an atom of sulphur, and three of oxygen.

What is known of the weights of atoms? 307. ATOMIC WEIGHTS.—Although the atoms of all substances are too small to be separately seen, chemists believe, not only that they have evidence of their existence, but that they know their relative weight. The relative weight of the atoms of a few of the elementary substances, as compared with the hydrogen atom, which is the lightest of all, is given in the following table, as nearly as it can be given in whole numbers.

How is the table which follows to be understood? 308. It is to be borne in mind that the table does not undertake to tell the absolute weight of the hydrogen atom, or of any other atom. This is not known. It only informs us that whatever may be the weight of the hydrogen atom, that of oxygen weighs eight times, that of sulphur, sixteen times, and that of carbon, six times as much : and so on of the other elements.

TABLE OF SOME OF THE MORE IMPORTANT ELEMENTS AND THEIR COMPOUNDS.

METALLOIDS.*

<i>Name.</i>	<i>Symbol.</i>	<i>Atomic weight.</i>
HYDROGEN, ...	H	1
OXYGEN, ...	O	8

METALLOIDS.

<i>Name.</i>	<i>Symbol.</i>	<i>Weight.</i>
Nitrogen, ...	N	14
Chlorine, ...	Cl	35
Phosphorus, ...	P	32
Sulphur, ...	S	16
Carbon, ...	C	6

METALS.

<i>Name.</i>	<i>Symbol.</i>	<i>Weight.</i>
Potassium, ...	K	39
Sodium, ...	Na	23
Calcium, ...	Ca	20
Magnesium, ...	Mg	12
Barium, ...	Ba	68

METALLOIDS WITH OXYGEN FORM ACIDS.

Nitric Acid, ...	NO_5
Chloric Acid, ...	ClO_5
Phosphoric Acid, ...	PO_5
Sulphuric Acid, ...	SO_3
Carbonic Acid, ...	CO_2

METALS WITH OXYGEN FORM OXIDES OR BASES.

Potassa, ...	KO
Soda, ...	NaO
Baryta, ...	BaO
Calcia, ...	CaO
Magnesia, ...	MgO

ACIDS WITH BASES FORM SALTS.

Nitrate of Potassa, ...	KO,NO_5	Sulphate of Potassa, ...	KO,SO_3
Nitrate of Soda, ...	NaO,NO_5	Sulphate of Soda, ...	NaO,SO_3
Nitrate of Baryta, ...	BaO,NO_5	Sulphate of Baryta, ...	BaO,SO_3
Nitrate of Calcia, ...	CaO,NO_5	Sulphate of Calcia, ...	CaO,SO_3
Nitrate of Magnesia, ...	MgO,NO_5	Sulphate of Magnesia, ...	MgO,SO_3

Each of the other acids forms its class of salts. There are other classes of acids, to be hereafter mentioned, which contain no oxygen.

What do metalloids form with oxygen? Give some examples.

What do metals form with oxygen? Give some examples.

What do acids form with bases? Name all of the salts which may be formed from the acids and bases above mentioned.

See page 141

309. EXPLANATION OF THE SYMBOLS.—

What do the
symbols stand
for? Give
examples.

The symbols may best be regarded by the student as standing for single particles of the several substances. Thus, N, Cl, P, K, Na, Ca, indicate respectively single atoms of Nitrogen, Chlorine, Phosphorus, Potassium, Sodium, and Calcium, and the numbers in the next column of the table indicate the relative weight of the atoms. In the case of compounds, the symbols also show their composition. Thus, NO_5 stands for a single molecule of Nitric acid, and, besides, indicates, as represented in the figure, that every such molecule is a compound molecule consisting of one atom of nitro-gen, and five atoms of oxygen.

What does
KO indicate?

310. Again, KO stands for a single molecule of Potassa, and indicates that it is a compound consisting of one atom of potassium and one of oxygen. Such a compound of two elements is called a *binary* compound.

What does
KO, NO₅ in-
dicate?

311. In the same manner KO,NO_5 stands for a single molecule of Nitrate of Potassa, and indicates that every such molecule is a compound, made up of two other compound molecules, one of nitric acid, and another of potassa. Such a compound, of two binary compounds, is called a *ternary* compound. The symbols may, indeed, be regarded as standing for larger quantities, in the same relative proportion; but it is an assistance in understanding chemical phenomena, to regard them as has been suggested. 

312. ATOMIC WEIGHTS OF COMPOUNDS.

How are atomic weights of compounds determined?

The relative weight of the atoms of simple substances is given in the table.

With the help of these and the symbols, the relative weight of the molecules of compounds is easily calculated. Thus, the symbol of nitric acid, being NO_5 , we know that 54 must be the weight of the molecule of nitric acid. For the symbol informs us that it is made up of a single atom of nitrogen (14) and five atoms of oxygen, (40). The weight of a molecule of potassa is 47, its symbol (KO) informing us, that it is made up of one atom of potassium, (39), and one atom of oxygen, (8).

313. CALCULATIONS OF WEIGHTS FROM

How are absolute weights calculated from symbols?

SYMBOLS.—From the symbols of compounds, the relative weight of their components may be calculated. NO_5 , being

the symbol of nitric acid, we know, as above shown, that the weight of its least particle is 54, and that this weight is made up of nitrogen, 14, and oxygen, 40. As a larger quantity is composed of precisely such particles, the relative weight of the constituents must be the same. Fifty-four pounds of nitric acid, therefore, contain 14 pounds of nitrogen, and 40 pounds of oxygen. In the same manner, from the symbol KO , with the help of the table of atomic weights, we ascertain that 47 pounds of potassa contain 39 pounds of potassium, and 8 pounds of oxygen. CaO, SO_3 , is the symbol of Sulphate of Lime or Gypsum. Adding the atomic weight of its constituents, we have 68 as the sum. Sixty-eight pounds of sulphate of lime, there-

fore, contain 20 pounds of calcium, 16 pounds of sulphur, and 32 pounds of oxygen.

Illustrate the law of definite proportions. 314. DEFINITE PROPORTIONS.—The composition of the same substance is always the same. When hydrogen and oxygen unite, in the proportion of one of the former to eight of the latter, they form water. (HO). If an excess of either element is employed, it remains uncombined. When they unite in a different proportion, as they do in another process, they form not a somewhat modified or changed substance, but an entirely new and distinct one, viz., peroxide of hydrogen, (HO₂) whose composition is also uniformly the same. So nitrogen combines with oxygen, in each one of the proportions indicated by the symbols, NO, NO₂, NO₃, NO₄, NO₅, in each case forming a new substance.

What is the law of multiple proportions? Give examples. 315. MULTIPLE PROPORTIONS.—As combination always takes place by whole atoms, and never by fractions, it is evident that whenever it occurs in more than one proportion, the others must be multiples of the first proportion or atomic weight. Thus the proportions, by weight, in which oxygen unites with nitrogen, are 8, 16, 24, 32, 40. In other than such exact proportions, combination never takes place.

What is a chemical equivalent? Give an example. 316. CHEMICAL EQUIVALENTS.—It has already been shown that the atomic weights express the proportions in which substances combine with each other. It also expresses, as would be naturally inferred, the proportions in which they replace each other, whenever such replacement occurs. Thus, chlorine sometimes expels

and replaces oxygen in chemical compounds. Whenever this takes place, 35 parts of the former, by weight, are required to replace 8 parts of oxygen. These numbers, therefore, express chemical equivalents of the two substances, and in general, a table of atomic weights, is also a table of chemical equivalents. So, when sulphuric acid expels nitric acid from any of its salts, it replaces it in the proportion of 40, to 54. The atom of sulphuric acid is the equivalent of that of nitric acid in another sense. It has precisely an equivalent effect in neutralizing the base with which this acid may be combined.

How is composition expressed by equivalents?

317. The composition of a mixture, is sometimes expressed by equivalents. Gunpowder, for example, may be described as containing one equivalent of sulphur, one of nitre, and three of carbon. This signifies that it is composed of 16 parts of Sulphur, 101 of nitre, and 18 of Carbon, as may be ascertained, by calculation, from the table of atomic weights.

How are the oxides named? Give examples.

318. NAMES OF OXIDES.—It will be observed from the table, that the oxide of potassium is called potassa; the oxide of sodium, soda, and so on, each oxide having a special name, derived from the name of the metal. The oxides of most of the other metals, not mentioned in the table, have no special names, but are called oxide of iron, oxide of lead, oxide of zinc, &c.

How are salts named? Give examples.

319. NAMES OF SALTS.—In naming the salts of the oxides last mentioned, the term oxide, is omitted, for the sake of

brevity. Thus, we say, nitrate of iron, sulphate of iron, phosphate of iron, instead of nitrate of oxide of iron, sulphate of oxide of iron, &c.

*How are oxides formed?
Give an example.*

320. FORMATION OF OXIDES. — Most of the oxides of the table are immediately formed as soon as their respective metals and oxygen come together. Thus, out of silvery potassium and transparent oxygen, white potassa is instantaneously produced. But, it is more commonly necessary to heat a metal with oxygen, to form its oxide. The oxides are also called bases. They are further considered in Part. III.

What compounds do chlorine, iodine, sulphur, &c., form?

321. As oxygen forms oxides, with metals, so chlorine, bromine, iodine, fluorine and sulphur, form, respectively, chlorides, bromides, iodides, fluorides, and sulphides. The latter are also called sulphurets.

*How are acids formed?
Give an example?*

322. FORMATION OF ACIDS. — Simple contact of a metalloid, and oxygen, is not generally sufficient to produce an acid. Heat is one among the additional means employed.

Thus, carbon or charcoal, heated with oxygen, or in air which contains it, is immediately converted into carbonic acid. Different acids are sometimes formed, by the combination of different proportions of oxygen, with the same substance. The names by which these are distinguished, are given, for reference, in the App.

*How are salts formed?
Give an example.*

323. FORMATION OF SALTS. — Most salts may be formed by simply bringing the proper acid and oxide together. Thus, as soon as liquid sulphuric acid and white

magnesia come together, they unite and form sulphate of magnesia or epsom salt. But the stimulus of heat is often required, particularly when the acid, as well as the oxide, is a solid substance. The affinity between acids and bases, is in accordance with the general law, that chemical attraction between substances is strongest, in proportion as they are most unlike, or opposed to each other, in their properties.

324. PROPERTIES OF ACIDS AND BASES.

What are the properties of acids and bases?

The properties of these two classes of compounds are opposite, and when brought together, they neutralize each other. Thus, when acid and soda are brought together, the acid taste of the former and the alkaline taste of the latter both disappear. Acids change certain vegetable blues to red. Bases restore the color. The experiment may be made with an infusion of litmus* in water. A leaf of purple cabbage answers the same purpose. Acids color it red, while potash and the alkalies change the red to green.

325. EFFECT OF HEAT TO PRODUCE COM-

What is the effect of heat on chemical combination?

BINATION.—It is seen from the foregoing, that heat is often essential to chemical combination. This is almost always the case where both substances are solid. Beside heightening their chemical affinity, heat has the effect of bringing the particles into closer and more general contact, and, within the range of affinity, by the melting

*Litmus is a blue vegetable pigment much used by chemists, for the purpose mentioned in the text.

or fusion which it accomplishes. Sulphur and iron, for example, require the aid of heat to bring about their union. The sulphur melts, and then combines with the iron.

Mention another effect of heat.

326. Further heating, has often just the contrary effect. It causes substances already combined, to separate from each other again. This is especially the case, when one of them is a gas. Thus, if oxide of silver or gold is heated, the oxygen passes off in the gaseous form and leaves the metal behind.

Why does heat have this effect?

327. Heat owes its decomposing effect, in this and similar cases, to the tendency which it imparts to certain substances, to assume the gaseous form. And as all bodies would, probably, be gaseous, at a sufficiently high temperature, sufficient heat would probably decompose all chemical compounds.

What is the effect of solution?

328. EFFECT OF SOLUTION.—The solution of one or both of two substances to be combined, has, in a multitude of cases, the same effect, in promoting chemical combination, as that produced by heat. The reason is also the same. It brings them into more general and thorough contact. This is illustrated in the case of ordinary soda powders, the two constituents of which, will not act on each other, unless one, at least, is dissolved.

What are the electrical relations of the elements?

329. ELECTRICAL RELATIONS OF ELEMENTS.—The metals are sometimes spoken of as electro-positive and the metalloids as electro-negative, for reasons given in the

chapter on galvanism. Electricity also resolves salts into the bases and acids which compose them. The acid goes to the positive pole, and is, therefore, electro-negative. The base goes to the negative pole, and is, therefore, electro-positive.*

* The laws of combination, and other subjects which belong to chemical philosophy, are further considered in the chapter on Salts, in the introduction to Organic Chemistry, and in the Appendix. Additional remarks on the atomic theory adopted in the text, are also given in the Appendix.

PART III.

INORGANIC CHEMISTRY.

The elements are divided into two great classes, metals (metals) and nonmetals (nonmetals).

CHAPTER I.

— as METALLOIDS. (not metals)

OXYGEN.

What is oxygen?

Where does it occur?

329. DESCRIPTION.—Oxygen is a transparent and colorless gas, a little heavier than the atmosphere. It is by far the most abundant substance in nature. Nearly one-fourth the weight of the air, eight-ninths of the ocean, and probably one-half of the solid earth, are oxygen.

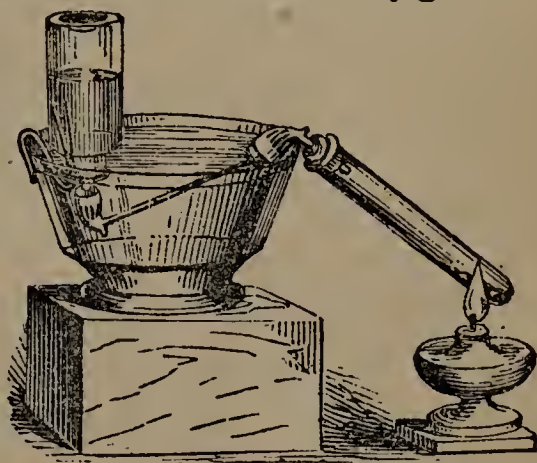
How is oxygen prepared?

330. PREPARATION.—Gaseous

oxygen is expelled from many substances which contain it, by the simple agency of heat. Chlorate of potassa and black oxide of manganese are such substances.

Give the complete process.

331. Mix equal quantities of these materials, and heat half a tea-spoonful of the



dry mixture in a test-tube, connected, air-tight, with two clay pipes, as represented in the figure. The connections are made by winding the pipe-stems with strips of wet paper, folded in such a manner that the stopper thus formed tapers slightly toward the end. The first portions of gas, which contain an admixture of the air of the tube, are allowed to bubble through the water and escape. The rest is made to rise into a half-pint vial, which it gradually fills, by displacing the water. The vial has been previously filled with water, then covered with a bit of glass, and inverted in the water. If it is desired to hang it on the side of the bowl, a hook is then introduced, made of strong, doubled wire, the two parts being kept about half an inch apart, and the vial is then hung, by its help, on the side of the bowl; or this may be dispensed with, and the vial held by the hand in its proper place, while the gas is collected. When the process is completed, vial and hook, if the latter has been used, are to be lowered into the bowl, the mouth being carefully kept below the surface; the hook is then removed, the mouth covered with a bit of glass, and the vial then inverted upon a plate containing a little water, and so kept until it is wanted for an experiment. All other gases, that are not absorbed by water, may be collected in the same manner.



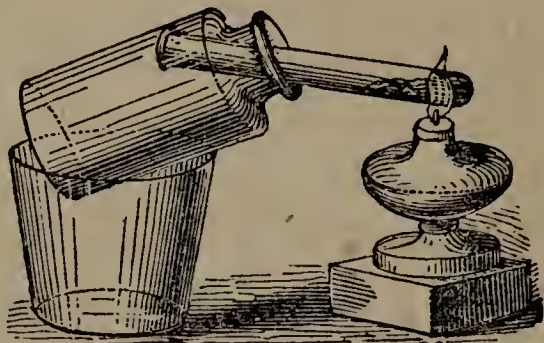
*Explain the
process.*

332. EXPLANATION.—Although black oxide of manganese may be employed as a source of oxygen, it does not yield this gas at the temperature employed in the above experiment. But,

for reasons not well understood, the admixture of this or any other infusible powder, facilitates the evolution of this gas from the chlorate. At a red heat, part of the double portion of oxygen which the black oxide contains is expelled in a gaseous form.

Give a simpler method of preparing oxygen

332. A SIMPLER METHOD.—The above method, for preparing oxygen, is here given, because it illustrates the mode of collection of gases in large quantities, and makes its accumulation visible to the eye. The oxygen needed for the following experiments will be more conveniently prepared by placing the mouth of the test-tube, containing the proper materials, in a wide-mouthed vial, and heating, as before. As the gas is evolved, it will expel the air, and soon fill the vial.



How can iron be burned in oxygen?

333. IRON BURNED IN OXYGEN.—Make a coil of very fine iron wire, by winding the latter around a pencil; fasten one end into the middle of a cork, by slitting the latter, and attach a fine splinter to the other end. Light the splinter, and introduce it into a vial of oxygen. The wire itself will take fire, and burn with brilliant scintillations. In this and the following experiments, the cork is to be placed loosely over the mouth of the vial, to prevent its violent expulsion by the heated gas.



What takes place in the above experiment?

334. EXPLANATION.—In this experiment the oxygen in the vial unites with the iron of the wire, and becomes solid, in the form of oxide of iron. The oxide fuses into a small globule on the end of the wire, and occasionally falls, and melts its way into the glass. This is apt to be the case, even when water is left in the bottom, so that a vial is likely to be destroyed by this experiment. The process is exactly the reverse of that which takes place when binoxide of manganese is heated, to produce oxygen. In the one case, oxygen was driven from the metal; in the other, it is drawn to it, though not in the same proportion.

Describe the taper experiment.

335. TAPER REKINDLED IN OXYGEN.—Introduce a newly extinguished taper or shaving, with a little fire at the end, into a vial of oxygen. It will be immediately rekindled. This experiment may be many times repeated without a new supply of gas.

Explain the last experiment.

336. Combustion is more vivid in pure oxygen, than in air, because the latter is diluted with other gases which do not take part in the combustion.

Describe the experiment with phosphorus.

337. COMBUSTION OF PHOSPHORUS.—Place a piece of phosphorus, of the size of a pea, on a piece of chalk, slightly hollowed out for the purpose and connected with a cork by a fine wire. Ignite the phosphorus and introduce it immediately into a bottle of oxygen. It



will burn with the utmost brilliancy, producing a light which the eye can scarcely bear.

What acid results from this experiment? 338. The white fumes which fill the bottle in this experiment, are composed of particles of phosphoric acid, which are produced by the union of the phosphorus and oxygen. They collect on the sides of the vial, and soon dissolve in water, which they absorb from the air. The water will be found to possess a sour taste, and to redden blue litmus paper, which is a characteristic of acids.

Describe the experiment with charcoal? 339. COMBUSTION OF CHARCOAL.—Attach a small piece of charcoal to a fine wire, ignite one end of it thoroughly, and introduce it into a vial of oxygen, having a cork at the other end, as before. It burns with brilliant sparks. A piece of charcoal bark is best adapted to this purpose.



What is produced in this experiment? 340. Carbonic acid is formed in the above experiment, from the union of carbon with oxygen. It is a gaseous acid, and cannot be seen. Neither can it be detected by its taste. But a piece of moistened litmus paper, held for some time in the bottle, will be reddened by it, and proof of the presence of an acid may be thus obtained. When wood burns it also yields carbonic acid.

Define combustion. 341. DEFINITION OF COMBUSTION.—All of the above experiments are cases of combustion, and combustion may be defined as combination of any two substances, attended by

light and heat. Metals which will not burn in the air, because it is diluted oxygen, burn brilliantly, as has been seen, in pure oxygen.

Why is heat required to start combustion?

342. PREVIOUS HEAT REQUIRED.—In order that most substances may burn, they must first be heated, to increase their affinity for oxygen. Take carbon, as an example. Before heating, its affinity for oxygen is not sufficient to bring about the requisite combustion. In this condition it may, therefore, lie for any length of time, in the air, or oxygen gas, without uniting with it. But heat stimulates the tendency to combination, and the bit of charcoal previously ignited, goes on burning until it is consumed. The first particles obtain the necessary stimulus of heat, from the previous ignition, the next from the burning of the first, and so on.

What kind of oxygen is required for combustion?

343. UNCOMBINED OXYGEN REQUISITE.—Mere presence of oxygen is not sufficient for combustion. It must be free, or uncombined oxygen. After burning charcoal in oxygen gas, the vial contains just as much oxygen as before, but being already combined, it has no affinity, or appetite, for more carbon, and therefore will not produce a new combustion.

If each particle is not heated, what takes place? Why?

344. EACH PARTICLE IN TURN MUST BE HEATED.—If the first particles that combine, do not communicate sufficient heat to the next, then the combustion stops. This may be illustrated by lighting a tightly wound roll of paper, and holding the flame upward. It is soon extinguished, because the heat that is produced

by the combustion of one portion of the paper, is not communicated to the next, but passes off into the air. But if the taper be held with the flame downward, each particle in turn receives the stimulus of heat necessary to combination, and the whole is consumed.

345. DECAY OF LEAVES AND WOOD.—

*What causes
the decay of
wood?*

The decay of leaves and wood is a sort of slow combustion, but not sufficiently vigorous to produce light and heat. In this case, as in the ordinary combustion of wood or coal, the particles which have combined with oxygen pass off into the air, in an invisible form.

346. BLEACHING.—

*How may
bleaching be
regarded?*

Bleaching may also be regarded as a kind of slow combustion. On exposing cloth to sun and air, its coloring matter is gradually burned up by the atmospheric oxygen.

347. OXYGEN A PURVEYOR FOR PLANTS.

*Explain how
oxygen is a
purveyor for
plants.*

It has been seen that both in combustion and decay, the oxygen of the air combines with the particles of leaves, and wood, and coal, and passes off with them in an invisible form. It flies off with them into the air, and yields them again to living plants, to produce new leaves and flowers, and fruits. Indeed, they are entirely dependent, for their support, on what they thus obtain from the death and decay of their predecessors, through the agency of this ever active purveyor, the oxygen of the air. But for the fact that the particles of vegetable and animal matter can thus be used again and again, the supply would

soon be exhausted, and vegetation cease upon the face of the earth.

348. OZONE.—By passing an electrical
How is ozone produced? current, continually, through oxygen gas, for some time, it becomes mysteriously changed in its proportions. In this changed condition it is called *ozone*. It is, as it were, intensified in its affinities by the current, so that like chlorine, it will attack silver, and exhibit many other of the properties of the latter gas. The electricity of the air has similar effects on the oxygen which it contains, and, in consequence of its varying electrical condition, the proportion of ozone is, also, from time to time, extremely varied. There is reason to believe that this substance has important influence upon health, and that either its deficiency or excess is injurious. In cholera seasons, it has been observed to be present in comparatively small quantity, while, during the prevalence of a species of influenza called 'grippe,' it is said to be more abundant. These observations need confirmation, by further experiments, before the facts can be regarded as fully established. The presence of ozone, is indicated by the discoloration, through the influence of a current of air, of a test paper, described in the section on chlorides.

349. RELATIONS TO LIFE.—Oxygen is
What relation to life does oxygen sustain? as essential to life, as it is to combustion. The diluted oxygen of the air, is better for breathing than pure oxygen, but that which contains much less than its due proportion, is no longer fitted to support life. Respiration consumes oxygen, so that the air of a close room is constantly being depri-

ved of this essential constituent without obtaining any new supply. As a consequence, it soon becomes unfit to breathe. The case is similar to that of a taper burned in a bottle. The oxygen of the air in the bottle is gradually consumed, and the flame grows gradually more and more dim till it goes out. So life grows fainter and fainter, in a close, unventilated room.

What is said of oxygen as a means of resuscitation? 350. Oxygen has been used, with great success, as a means of resuscitation, in cases of suffocation and drowning, when similar use of air was without effect. In such cases, it is forced into the lungs through a tube, from a jar or bladder.

CHLORINE.

What is chlorine? 351. DESCRIPTION.—Chlorine is a yellowish green gas, of peculiar odor, about $2\frac{1}{2}$ times as heavy as the air. More than one half of common salt is chlorine. Salt mines and the ocean, therefore, contain it in immense quantities.

Where is it found? 352. PREPARATION.—Chlorine is prepared from muriatic acid, which is composed of chlorine and hydrogen, by using some agent to retain the latter and liberate the former. Black oxide of manganese is such a substance.

How is chlorine prepared? 353. The oxide is well covered with muriatic acid, and kept warm, as the evolution of the gas proceeds. This is best effected by a cup of hot water, as represented in the figure. Chlorine gas soon displaces the air in the second vial. It should be corked as soon as filled.



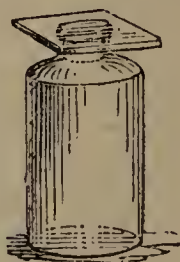
Explain the process.

354. It will be remembered that black oxide of manganese, is a substance containing a large portion of oxygen, part of which is feebly held, and very willing to go. Its use in making chlorine depends on this fact. The loosely held oxygen, seizes upon the hydrogen of the muriatic acid, remaining with it as water, and at the same time setting its chlorine at liberty.

Describe another method of preparing chlorine.

355. A SIMPLER METHOD.—Acids expel chlorine from many bases which have previously been made to absorb it. Lime is one of these bases. Pour

into a wide-mouthed, half-pint vial, a table spoonful of dilute sulphuric acid, and add rather more than the same bulk of chloride of lime or bleaching powder. It is best to add it in small portions, covering the vial with a cork or bit of glass after each addition.



The vial will soon be filled with faintly green chlorine gas. More of the materials will be required, if the chloride of lime is deteriorated by exposure to the air, as is often the case. The gas thus produced, may be used for most of the experiments which follow, without transferring it to another vessel.

What proof that chlorine is heavier than air?

356. CHLORINE HEAVIER THAN AIR.—This is already imperfectly proved, in the first method of collecting chlorine, but the following proof is more satisfactory. The gas produced in the last experiment, may be slowly poured from the vessel containing it, into

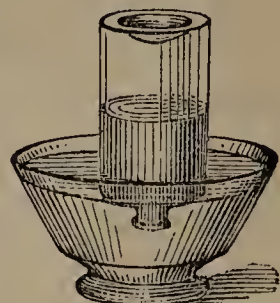


another wide-mouthed vial. The second vial, if the smaller of the two, may be thus filled without receiving any acid from the first. In small quantities the gas cannot be seen to flow, but will actually pass from one vessel into the other. Its presence may be proved by the methods given in the following experiments.

357. CHLORINE DISSOLVES IN WATER.—

*What proof
that chlorine
dissolves in
water?*

Having filled a vial with chlorine, by the first of the methods above described, cork it, and open it under water, contained in a bowl. As the gas dissolves in the water, the latter will rise to take its place. When it has risen a little way, cork and shake the vial, and open it again below the surface. The water will then rise and dissolve still more of this gas. The solution is to be set aside for a subsequent experiment. Gas produced by the second method above described, may also be used in this experiment, if previously transferred to another vial.



358. ACTION OF CHLORINE ON METALS.

*Describe the
action of chlo-
rine on metals.*

Chlorine gas combines with many metals, converting them into chlorides. Their action may be illustrated by sprinkling finely pulverized antimony into a bottle of chlorine. Each particle of metal ignites as it falls through the gas, and a miniature shower of fire is thus produced. The white smoke which is produced in this experiment, is composed of minute particles of chloride of antimony.

What is the action of nascent chlorine?

359. NASCENT CHLORINE.—Nascent chlorine, in its action on the metals, is the most powerful agent known. Even the noble metals yield to its power, and waste away in the liquid which contains it. The term *nascent* signifies being born, or in the act of formation.

What is the general fact in relation to nascent bodies?

360. All gases are most energetic, in their action at the first moment of their separation from compounds which contain them, and while they may be regarded as still retaining the solid form themselves. The subsequent expansion into the gaseous form, diminishes their energy.

How is nascent chlorine best obtained?

361. Nascent chlorine is best obtained by mixing hydrochloric acid with half its bulk of strong nitric acid. Such a mixture is called *aqua regia*. The latter acid compels the former to yield a constant supply of its own chlorine in the nascent condition. It does this, by means of its oxygen, which seizes upon the hydrogen of the hydrochloric acid, forming water, and sets its chlorine at liberty. The remnant of the nitric acid escapes, as in the case of its action on metals hereafter described.

Does chlorine decompose water?

362. CHLORINE DECOMPOSES WATER.—If chlorine water be exposed to the sun for some days, it loses its green color. The chlorine combines with the hydrogen of the water, forming hydrochloric acid, and sets its oxygen at liberty. If the experiment be made in a bottle, inverted in water, so that the



oxygen may collect, bubbles of this gas will be found above the liquid. This experiment proves the powerful affinity of chlorine for hydrogen.

How is calico bleached by chlorine? 363. BLEACHING BY CHLORINE.—Introduce bits of calico into the solution of chlorine before obtained. Most colors will soon disappear. If the solution is weak, the bleaching effect will be better shown with infusion of litmus or red cabbage. Color may also be removed from cloth or paper by hanging the article to be bleached, previously moistened with water, in a vial of gaseous chlorine.

How is chlorine water best prepared? 364. Chlorine water may be prepared in larger quantity, by leading the gas directly into water. The first of the two methods before described, will be found the most advantageous.

Explain how chlorine bleaches. 365. OXYGEN THE REAL BLEACHING AGENT.—The real bleaching agent in this method of bleaching, is the same as that mentioned in paragraph 346. It is oxygen, always present during the process, as an element of the water which moistens the material. The chlorine simply acts to bring nascent oxygen into activity. It does this by depriving it of the hydrogen with which it is combined. The oxygen having thus lost its companion, looks about, as it were, for something else with which to combine. The coloring matter of the cloth being the first thing at hand, is destroyed by the extreme energy of its affinity.

Show the advantage of nascent oxygen.

366. ACTION OF NASCENT OXYGEN.—The superior force of an element in its nascent condition is strikingly shewn in the above experiment. A piece of calico hung in a bottle of oxygen gas would not lose its color. But the nascent oxygen which chlorine liberates, begins to destroy the coloring matter on the first instant of its liberation.

Describe the inflaming of turpentine by chlorine.

367. CHLORINE AND TURPENTINE.—Immerse a rag wet with camphene or spirits of turpentine in a vial of chlorine gas. It is immediately inflamed, with the production of dense black smoke. Spirits of turpentine is composed of hydrogen and carbon. The former combines so energetically with chlorine, as to produce flame in the above experiment, while the latter is separated in the form of black particles, which constitute the smoke.



Is chlorine a disinfectant? Why?

368. USE AS A DISINFECTANT.—As chlorine destroys color, when used as a bleaching agent, so it destroys noxious vapors in the air. Its minute atoms fly forth like birds of prey, seizing on the impurities of the atmosphere and devouring them. Chloride of lime is commonly substituted for chlorine for this use. A little of this salt is placed in a saucer and moistened, when it gradually yields chlorine through the action of the carbonic acid of the air. Stronger acids evolve it abundantly.

369. CHLORINE A DESTRUCTIVE AGENT.

*What is said
of chlorine as
a destructive
agent?*

Chlorine, as has been seen, is one of the most destructive of all substances. It not only destroys colors and odors, but any kind of vegetable or animal matter long submitted to its action, wastes away and is destroyed. It does this partly by its own direct action, and partly by letting loose the atoms of nascent oxygen, as before described.

370. IN WHAT SENSE DESTRUCTIVE.—It

*In what sense
is it destruc-
tive?*

is always to be borne in mind that the term destruction is used in chemistry in an entirely figurative sense. Thus, neither oxygen nor chlorine, strictly speaking, destroy. They only combine with the particles of the substances they seem to destroy, forming new, and often invisible compounds. Many of these will be hereafter mentioned.

371. RELATIONS TO ANIMAL LIFE.—Chlo-

*Give the rela-
tions of chlo-
rine to animal
life.*

rine is a poisonous gas. No danger, however, is to be apprehended from the escape of small portions into the air during the preceding experiments. The diluted gas, however, is apt to produce irritation of the throat and consequent coughing.

372. RESEMBLANCE TO OXYGEN.—In

*In what re-
spects does
chlorine re-
semble oxy-
gen?*

many respects chlorine is similar to oxygen, as has already been shown. It combines with almost all of the elements, and with many compounds. This combination is often attended with light and heat, and is therefore combustion. The metal antimony, for example, as has

already been shown, will burn in chlorine gas even without kindling.

Mention some compounds of chlorine and oxygen.

373. COMPOUNDS OF CHLORINE AND OXYGEN.—Chlorine combines with five atoms of oxygen to form chloric acid. This acid is of importance, principally, as a constituent of the chlorate of potassa, analagous in its leading properties to nitrate of potassa. Hypochlorous acid, a constituent of bleaching powders, is another compound of chlorine with oxygen. It is again mentioned in the section on Chlorides.

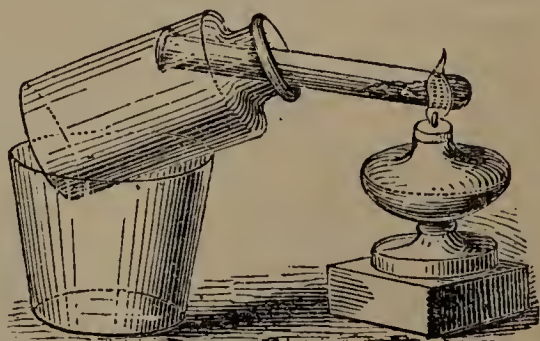
IODINE.

What is iodine? Where is it found?

374. DESCRIPTION.—Iodine is commonly seen in the form of brilliant blue-black scales, somewhat similar to plumbago in appearance. In odor it resembles chlorine. It is found in the water of the ocean, in sea-weeds, sponges, &c., but always in combination with sodium or some other metal. Minute traces of it are found to exist in the atmosphere, and thence are transferred to the bodies of animals.

Explain the manufacture of iodine?

375. PREPARATION.—For the preparation of iodine, a lye made from the ashes of certain sea-weeds is heated with oil of vitriol and black oxide of manganese. The liberated oxygen of the latter expels va-



pors of iodine from the mixture. These being led into a receiver, crystallize in brilliant scales. A retort and receiver are commonly used in the process. The ashes of sea-weed employed for the purpose are called *kelp*, and are prepared in great quantities on the coast of Scotland.

376. VIOLET VAPORS OF IODINE.

How are violet vapors of iodine produced?

Introduce a few scales of iodine into a test-tube or vial, and heat it for a moment over the spirit lamp. The solid iodine is immediately converted into a beautiful violet vapor, which fills the vial. As the latter cools, the iodine becomes again solid, in the form of minute crystals. On warming these crystals the color re-appears.



377. COLORING EFFECT ON STARCH.—

Describe the effect produced by iodine on starch paste.

Heat a little iodine in a pipe bowl, and as soon as vapors appear, blow them against a sheet of paper covered with figures



made with thin starch paste. The iodine vapor immediately colors them blue. The paste may be made in a test-tube, over a spirit lamp.

378. ENGRAVINGS COPIED BY IODINE.—

How are engravings copied by iodine?

A transient copy of an engraving, or other printed matter, may be made, by exposing it to faint fumes of iodine, and then pressing it down upon paper moistened with vinegar, or dilute nitric acid. The vapors, adhere to the ink only, and are transferred by pressure; producing, with the starch contained in ordinary letter paper, a blue impression.

BROMINE.

379. Bromine is a dense reddish-brown fluid, exhaling at ordinary temperatures a deep orange-colored vapor. It is similar, in its chemical properties, to chlorine, but the latter is the stronger of the two and expels bromine from its compounds. Thus, if chlorine be passed into one end of a heated tube containing bromide of silver, the vapors of bromine will be seen to pass out at the other end, and escape, while the chlorine remains, and takes possession of the metal. Bromine, like chlorine, is found in sea-water and in the water of mineral springs, combined with sodium or some other metal. The power of chlorine to expel it from its compounds, is made use of in manufacturing bromine. This substance is used in photography, but is otherwise of little general interest. Although widely distributed, it exists in nature in comparatively small quantities. Bromine vapors have the effect of imparting to starch a beautiful orange color.

FLUORINE.

380. Fluorine is a yellowish-brown gas, of strong odor, somewhat similar to that of chlorine. It is one of the elements of the beautiful mineral *fluor spar*. It is prepared from the fluoride of potassium, by means of the galvanic current. Its isolation has been attended with great difficulties, and the

gas is therefore imperfectly known. Its principal compounds are hydrofluoric acid and fluor spar, to be hereafter described.*

SULPHUR.

What is sulphur? Where does it occur? 381. DESCRIPTION.—Sulphur is a brittle yellow solid, burning with a peculiar odor made familiar in the ignition of common friction matches. With the metals it forms sulphides or sulphurets. In Sicily and certain other volcanic regions, it occurs in beautiful, yellow crystals. Gypsum, and iron pyrites or fools gold, represent the two principal classes of minerals that contain it. It also enters in small proportion into the composition of all animal and vegetable substances. It is the sulphur in eggs that blackens the silver spoon with which they are eaten.

Describe the manufacture of sulphur? 382. PREPARATION.—In preparing commercial sulphur, the impure material of volcanic regions is highly heated, and thus made to fly off as vapor, leaving its earthy impurities behind. The vapors are condensed as flowers of sulphur. The process by which a solid is thus vaporized, and re-converted into a solid, is called *sublimation*. Native sulphur may also be partially purified by simple fusion. Its earthy impurities having settled, it is poured off into moulds and thus converted into roll brimstone.

* Many compounds of chlorine, bromine, iodine and fluorine, with each other and with oxygen, are known to the chemist, but they are without interest to the general student.

How may the sublimation of sulphur be shown?

of sulphur will deposit in the upper portion of the tube.

383. SUBLIMATION OF SULPHUR.—

The sublimation of sulphur may be shown by heating a small bit of the substance in a test-tube. Flowers

will deposit in the upper portion of

the tube.



What is said of the combustion of sulphur?

Melt some flowers of sulphur upon the end of a wire wound with cotton thread, and hang them after ignition in a vial of oxygen gas. The oxygen gas combines with the sulphur, forming a new compound gas, called sulphurous acid. A brilliant blue flame accompanies the combination. It thus appears that acids may be gaseous as well as liquid. The acidity may be proved, as usual, by blue litmus paper.

384. COMBUSTION OF SULPHUR.—

Melt some flowers of sulphur upon the end of a wire wound with cotton thread, and hang them after ignition in a

vial of oxygen gas. The oxygen gas com-

brates with the sulphur, forming a new com-

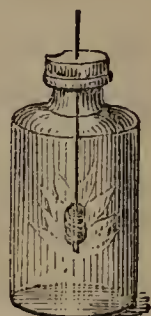
ound gas, called sulphurous acid. A bril-

liant blue flame accompanies the combina-

tion. It thus appears that acids may be gase-

ous as well as liquid. The acidity may be

proved, as usual, by blue litmus paper.



Describe the process of bleaching by means of sulphur?

385. BLEACHING BY SULPHUR.—Intro-

duce a red rose or other flower into a vial filled with sulphurous acid. It will soon

lose its color. Wash it with dilute sulphu-

ric acid and the color re-appears. This experiment

may also be made in a bottle in which sulphur has

been burned in common air.

Why does sulphurous acid bleach?

386. EXPLANATION.—Sulphurous acid

forms a white compound with the red coloring matter of the rose. It may seem incom-

prehensible that a colorless gas and red coloring matter should unite to form white, and it would be so, were the case one of mere mixture. But it is an

instance of chemical combination, in which, as is often the case, the properties of the constituents entirely disappear. When sulphuric acid is afterward used, the color re-appears, because the stronger acid has expelled the weaker and has itself no inclination to form with the coloring matter a similar combination.

Describe the process of straw bleaching. 387. STRAW BLEACHING.—The bleaching of straw goods is always effected by sulphurous acid. They are first moistened, and then exposed to the fumes of burning sulphur. An inverted barrel is often made to serve the purpose of a bleaching chamber. Articles thus bleached by sulphurous acid, after a time, regain their color. This is not the case in chlorine bleaching, because the coloring matter is not merely changed, but destroyed. This agent is not applicable to straw, on account of a faint brown tinge which it imparts to the material.

Explain the copying of medallions by sulphur. 388. COPYING MEDALLIONS. — Sulphur melts, readily, by application of heat. At a higher temperature it thickens again. Still further heating makes it again fluid. In this second period of fluidity, it has the remarkable property of assuming a waxy consistence on being poured into water. In this condition it is used for copying seals, coins, and medals. The copy acquires, in a few hours, the original hardness of sulphur. The plastic material may be obtained in the form of elastic



strings, by pouring molten sulphur from a test-tube into cold water.

How may crystals of sulphur be obtained?

389. SULPHUR CRYSTALS.—Sulphur may be obtained in a crystalline form, by melting it in a pipe bowl, at a gentle heat, and then allowing it to cool. A crust

soon forms on the top, which is broken, and a portion of the liquid sulphur below poured out.



On breaking the pipe, it is found filled with crystals, shooting across the interior from the encrusted walls.

SULPHURIC ACID.

Describe sulphuric acid.

390. DESCRIPTION.—Sulphuric acid is a colorless, oily fluid, of intensely acid taste, known in commerce as *oil of vitriol*. It is composed of sulphur and oxygen, in the proportion of one atom of the former to three of the latter. It also contains water, with which it is chemically combined. As it is among the most important of all chemical products, the process of its manufacture will be given with some detail.

How may sulphuric acid be prepared?

391. PREPARATION.—Sulphuric acid may be made directly from its elements, by igniting a mixture of air and vapor of sulphur with a red-hot iron. In quantity, it is always made from sulphurous acid, by imparting to the latter additional oxygen. Take a bottle in which sulphur has been burned, and which, therefore, contains sulphurous acid, and hold in it, for a short time, a rod or stick

moistened with nitric acid. The gaseous sulphurous acid obtains oxygen from the nitric acid, which is rich in this element, and very liberal of it, and thereby becomes sulphuric acid. A little water, previously placed in the bottom of the vial, absorbs the acid thus formed. To acidify the water to any considerable extent, it will be necessary to burn sulphur, and introduce the moistened rod repeatedly. That the acid is not the sulphurous or the nitric acid, employed in the process, may be proved by using it to make hydrogen gas.



What causes the red fumes in the above experiment?

392. REMARK.—The red fumes which fill the vial in the last experiment, consist of the changed nitric acid, (nitric oxide,) which has just given up part of its oxygen, and is now resuming part of it from the air. It thereby becomes a third substance, of a red color, to be again mentioned in the section on nitric acid.

Explain how sulphuric acid is manufactured.

393. MANUFACTURE OF OIL OF VITRIOL.—The method of the production of oil of vitriol on a large scale, is essentially the same as that above given. Fumes of burning sulphur and vapor of nitric acid, with air and steam, are introduced into a leaden chamber, when the process proceeds, as before described.

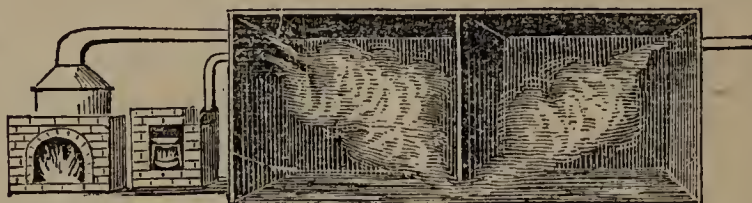
Why is but little nitric acid required?

394. Comparatively little nitric acid is needed in the process, for it is found that while it yields oxygen to the sulphurous fumes, the changed acid greedily seizes oxygen from the air of the chamber, and imparts it again, to keep up

the process. The air is, therefore, the real oxidizer, while the changed nitric acid only acts to transfer it to the sulphurous fumes.

Describe the acid chambers. 395. DESCRIPTION OF ACID CHAMBERS. The figure represents one form of the

leaden chambers employed in the above manufacture. Connected with them



are a steam boiler and two furnaces, in one of which sulphur is burned, and converted into sulphurous acid. Over the sulphur is another vessel, containing the materials for making nitric acid, the formation of which commences as soon as the sulphur flame has imparted the requisite heat. The vapors thus produced, are mingled with air and steam in the leaden chamber. How they act together to produce sulphuric acid, has been already explained. The space is divided by a partition, in order that all the materials may be more thoroughly mixed, as they pass through the narrow opening below it. The acid, as it forms, dissolves in water which covers the bottom of the chamber, and is thus collected. Lead is used as a lining for the chambers, because the acid would destroy almost any other material that might be employed.

How is the chamber acid concentrated? 396. The dilute acid obtained from the chambers, is concentrated first in leaden vessels, and afterward, when it has become strong enough to corrode the lead, in retorts of platinum. The metal platinum being of about half the value of

gold, the vessels in which the evaporation is carried on are extremely expensive. Some manufactories deliver tens of thousands of pounds of sulphuric acid per day.

How is the strength of sulphuric acid shown?

397. COMPARATIVE STRENGTH OF SULPHURIC ACID. — Sulphuric acid is the strongest of all acids. This may be shown by bringing it to a direct trial of strength with other strong acids. If poured, for example, on nitrate of potassa, which is, as its name implies, a compound of nitric acid and potassa, it takes sole possession of the base and expels the nitric acid in the form of vapor. It expels muriatic acid from its compounds in the same manner. This is the method by which nitric and muriatic acids are always obtained. Whatever they can accomplish when free, may therefore be traced back to the power of sulphuric acid which gave them their liberty. The latter is the king among the acids, who accomplishes indirectly, what he cannot effect in person. The solution of the noble metals by aqua regia is one among these indirect results.

Is it strongest at high temperatures?

398. Sulphuric acid is volatile at high temperatures. Phosphoric and other non-volatile acids, are, therefore, under certain circumstances, superior to it. This is illustrated in certain crucible operations, where compounds containing sulphuric acid are heated with such acids. The sulphuric acid is then easily dispossessed, and compelled to take refuge in flight.

What is the action of sulphuric acid on metals.

399. ACTION OF SULPHURIC ACID ON METALS.—Sulphuric acid attacks all metals with the exception of platinum and gold.

Even the dilute acid acts on all the metals hereafter named, as far as manganese.

Illustrate the action of the dilute acid.

400. The action of the dilute acid may be illustrated, by placing a few bits of zinc in a tumbler, with a little water, and adding a small portion of oil of vitriol. The metal dissolves with the evolution of hydrogen gas. The reason of the evolution of this gas is given in the section on Hydrogen.

Illustrate the action of the strong acid.

401. The action of the strong acid may be illustrated, by heating a little copper, with oil of vitriol, in a test-tube. The metal dissolves with the evolution of sulphurous acid fumes. The reason of the appearance of sulphurous acid will be given in the next section.

What of the affinity of sulphuric acid for water?

402. AFFINITY FOR WATER.—The affinity of sulphuric acid for water is so strong that it lays hold on every particle of the invisible aqueous vapor of the atmosphere. It finds it in what seems the driest air; and every particle which it catches it retains. It grows in bulk by what it thus drinks, as will be seen if a little oil of vitriol is left exposed to the air, for a few days, in an open vessel. It is sometimes necessary, in chemical operations, to free gases from all the aqueous vapor which is mixed with them. This is done completely by causing them to bubble through oil of vitriol, and again collecting them.

What takes place when sulphuric acid is diluted?

403. HEAT BY DILUTION.—When sulphuric acid and water are mixed, condensation takes place, accompanied by elevation of temperature. Fifty cubic inches of

sulphuric acid and fifty cubic inches of water, when mixed, do not fill a vessel of the capacity of one hundred cubic inches, but fall about three inches short. Condensation has therefore taken place to the amount of three inches. Heat is, as it were, pressed out in such cases, as explained in the early part of this work.

Why does sulphuric acid char wood? 404. WOOD CHARRED BY SULPHURIC ACID.—Wood dipped in oil of vitriol is soon charred. Wood is composed of carbon, hydrogen and oxygen. The last two together form water. The affinity of sulphuric acid for water has been mentioned above. The acid and the wood being in contact, it would seem that the hydrogen and the oxygen of the latter agree to combine and satisfy this demand. The carbon being at the same time isolated, appears in its natural black color. Sulphuric acid exerts a similar action on other vegetable substances.

What are the uses of sulphuric acid? 405. IMPORTANT USES.—Sulphuric acid is largely employed for dissolving indigo, for use in dyeing and calico printing; also, for converting common salt into sulphate of soda, as a preparatory step to the manufacture of carbonate of soda. It is also essential in the manufacture of superphosphate of lime, an article now extensively used in agriculture. Nitric and muriatic acids are produced through its agency from nitre and common salt.

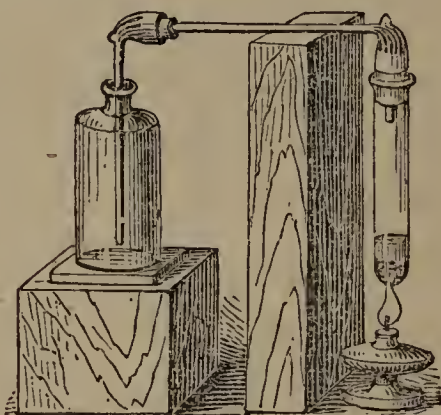
SULPHUROUS ACID.

What is sulphurous acid? 406. DESCRIPTION.—Sulphurous acid is a gas, having the smell of a burning match.

It is composed of sulphur and oxygen, in the proportion of one atom of the former to two of the latter. The termination "ous" indicates, as in other cases, a smaller proportion of oxygen than is contained in some other acid composed of the same elements.

How is sulphurous acid prepared?

407. PREPARATION.—It has already been shown that this acid may be prepared by burning sulphur in oxygen. Another, and better method is to heat oil of vitriol with bits of copper. The oil of vitriol is thus deprived of part of its oxygen, and converted into sulphurous acid. The process may be conducted in a test-tube. By leading the gas through a smaller tube into a vial partly filled with water, a solution of sulphurous acid may be obtained, possessed of the same bleaching and other properties as the gas itself. When the evolution of the gas commences, the heat of the lamp is no longer required.



Explain the process.

408. EXPLANATION.—Copper has a very strong affinity for oxygen, and takes it from the oil of vitriol, which possesses it in large proportion. The oil of vitriol, thus deprived of part of its oxygen, is converted into sulphurous acid gas.

Why is sulphurous acid sometimes added to wines?

409. USE IN PRESERVING WINES.—Sulphurous acid, in small quantities, is sometimes added to wine to prevent its souring. This change is owing to the absorption of oxygen from the air. Sulphurous acid is a

substance possessed of an excessive appetite or affinity for oxygen. A small portion of it in a wine cask will seize on what little oxygen finds admission, and so prevent the deterioration of the wine. It destroys itself in this act of protection, and is converted into sulphuric acid.

How is sulphurous acid employed in manufacturing sugar?

410. USE IN SUGAR MANUFACTURING.—

The oxygen of the air so modifies the juice of the sugar-cane, that it cannot be made to yield its due proportion of sugar. Sulphurous acid, by appropriating the oxygen to itself, prevents this effect, and is said to double the product. It is generally used in the form of its lime compound, called sulphite of lime. The objection to its use consists in the slight sulphurous taste which it imparts to the sugar. But this is said to be removed by clarification, at a loss of ten per cent., leaving still a large gain from the employment of the process. The bleaching effects of sulphurous acid have already been illustrated.

NITROGEN.

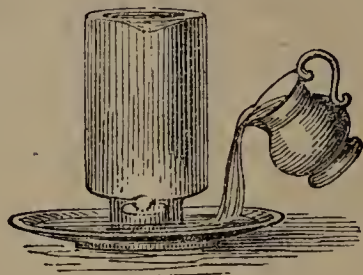
*What is nitrogen?
Where is it found?*

411. DESCRIPTION.—Nitrogen is a transparent gas, without taste or odor. It forms about four-fifths of the air we breathe. It occurs also in combination with other elements in a solid form. One-fifth of the weight of the dried flesh of animals is nitrogen. It also enters into the composition of nitre and other salts.

How is nitrogen prepared? 412. PREPARATION.—Nitrogen is prepared from ordinary air by removing its oxygen. For this purpose a small portion of phosphorus is floated on a slice of cork upon water, and then kindled, and a vial inverted over it.

As it burns it abstracts the oxygen; the water rises to take its place, and what is left of the air is nitrogen.

The cork should be a little hollowed out, and chalk scraped into the cavity. Water must be poured into the saucer as the first portion rises into the bottle. The bottle is then cooled, either by water or long standing, and corked while yet inverted. It is then shaken, to wash the gas. A piece of phosphorus, of the size of a large pea, is sufficient for the preparation of half a pint of gas.



Explain the process.

413. EXPLANATION.—The burning phosphorus selects all of the oxygen atoms in the air, and, by combining with them, converts them into solid particles of a certain oxide of phosphorus called phosphoric acid. These particles at first appear as a white smoke, and are afterward dissolved in the water.

Does nitrogen extinguish flame? Why?

414. NITROGEN EXTINGUISHES FLAME.—If a burning taper be lowered into the bottle of nitrogen, as above prepared, it will be immediately extinguished. Flame is the brightness which accompanies active chemical combination, but here is nothing to combine. Nitrogen is a sloth among the elements, possessing no degree of chemical activity.

415. PRINCIPAL OFFICE OF NITROGEN.—

What is the principal office of nitrogen?

The principal office of the nitrogen of the air is to dilute its oxygen. The latter, if pure, would soon consume our bodies as it hastens the combustion of a taper or other combustible.

416. THE ATMOSPHERE.—

What is the composition of the air?

The air we breathe, and which, to the depth of fifty miles or more, forms the crystal shell or envelope of the globe we inhabit, is a mixture of nitrogen and oxygen gases with aqueous vapor. It also contains small and varying proportions of carbonic acid and ammonia.

417. PROOF THAT AIR IS A MIXTURE —

How is it proved to be a mixture?

That it is a mixture, and not a chemical compound, is sufficiently evident from the fact that it possesses no new and peculiar properties different from those of its constituents. It is further proved to be a mixture, from the fact that heat, which is the usual attendant on chemical combination, is never occasioned when air is artificially produced by the admixture of its constituents.

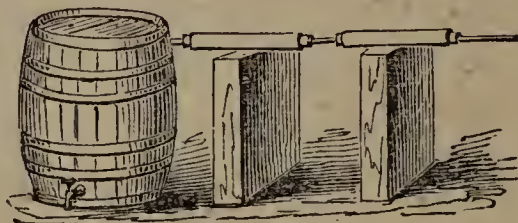
418. USE OF CARBONIC ACID AND AMMONIA

What purpose is served by its carbonic acid and ammonia?

IN THE AIR.—Carbonic acid and ammonia, although present in the air in extremely small quantity, subserve the most important purposes in administering to the growth of plants. They constitute the gaseous food of all forms of vegetable life, as will be more fully explained in succeeding chapters of this work.

How is the proportion of nitrogen determined?

419. ANALYSIS OF THE AIR.—The method by which the relative amount of oxygen and nitrogen in the air is determined has been already given. On burning phosphorus under a glass jar, as there described, the water is found to rise and fill a little more than one-fifth of the vessel, thereby indicating that one-fifth of the air which it contained was oxygen gas. The remaining $\frac{4}{5}$ ths is nearly all nitrogen. In accurate experiments, a graduated tube is employed, instead of a jar or tumbler. It is not essential that the phosphorus should be ignited. Without ignition, it will gradually combine with all the oxygen, and remove it from the air contained in the tube.



How is the amount of carbonic acid water and ammonia determined?

420. In order to determine the amount of aqueous vapor and carbonic acid in the atmosphere, a gallon or other measured quantity of air is drawn through tubes containing materials to absorb these substances. This quantity is known by the increased weight of the tubes after the experiment is completed.

Describe the apparatus used in this analysis.

421. THE APPARATUS DESCRIBED.—The apparatus used in the experiment is represented in the last figure. It consists of a bottle or small cask, filled with water and provided with a cock below. The cock is turned, and as the water flows out, air flows in through the tube to take its place. The quantity of air that has passed

through the tubes is known by the quantity of water that has flowed out from the cask. The materials employed in the tubes are pumice stone drenched with oil of vitriol, in the first, to absorb the water; and caustic potassa, in the second, to retain the carbonic acid. The method for determining the amount of ammonia in the atmosphere is essentially the same; muriatic acid being used as the absorbent.

422. PROPORTIONAL COMPOSITION OF

What are the proportions of the different constituents of the atmosphere?

THE AIR.—The proportions of the four constituents of the air above mentioned, as obtained by the method just described, are about 21 per cent. of oxygen, 79 of nitrogen, $\frac{1}{2500}$ th of carbonic acid, and $\frac{1}{1000000}$ th of ammonia. The proportion of aqueous vapor is extremely variable. That of carbonic acid and ammonia is also variable to a considerable extent.

NITRIC ACID.

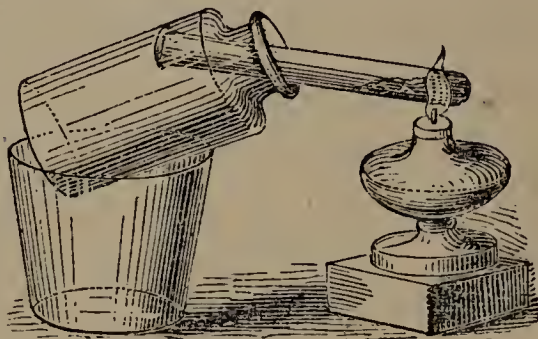
What is nitric acid?

423. DESCRIPTION.—Nitric acid is a thin, colorless and intensely acid fluid. It corrodes metals instantaneously, with the evolution of deep red vapor. It is composed of nitrogen and oxygen, in the proportion of one atom of the former to five of the latter. It contains, in addition, water, with which it is chemically combined. It is possible to make it anhydrous, or free from water, but such an acid is never used.

How is nitric acid prepared?

424. PREPARATION.—Nitric acid exists in a dormant state in ordinary saltpetre.

Its affinities being entirely satisfied by the potassa with which it is combined in that substance, it lies there perfectly inactive. Sulphuric acid being stronger, has the power of taking its base, and expelling the acid in the form of vapor. In order to collect and condense the acid fumes, the mixture may be made in a test-tube, the mouth of which opens



into a vial or flask. It is necessary to keep the vial covered with porous paper or cloth, and to moisten it frequently in order to maintain its coolness. Where larger quantities are prepared, a retort and well-cooled receiver are employed, as represented in the Appendix.

*What effect
has nitric acid
on metals?*

425. OXIDATION OF METALS.—If a little nitric acid is poured upon a copper coin, placed in a capsule or saucer, the coin will immediately begin to dissolve. It is not, strictly speaking, the metal which dissolves. One portion of the acid first converts the metal into oxide, by giving it part of its own oxygen. It thereby destroys itself, while another portion of undecomposed acid dissolves the oxide which is formed. One portion, in reality, sacrifices itself to satisfy the appetite of the other. Most other metals are similarly acted on by nitric acid.

*What is nitric
oxide?*

426. NITRIC OXIDE.*—The vapors which are given off in the last experiment are

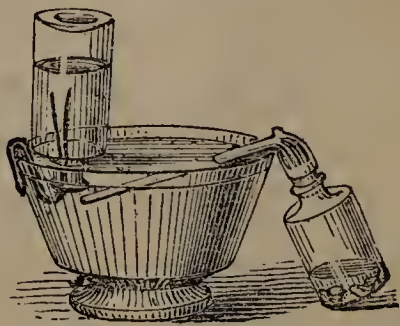
* It will be observed that the term oxide is sometimes applied to compounds of the metalloids with oxygen. (See chap. iii., Inorg. Chem.)

nitric oxide, changed by the air into which they rise. The nitric oxide is, so to speak, the fragment of nitric acid, which is left after three atoms of its oxygen are abstracted. Rising into the air, it combines with oxygen enough partly to supply the place of that it has just lost, and is thus converted into red fumes of peroxide of nitrogen containing four atoms of oxygen. This compound is also called hyponitric acid. Still another compound of nitrogen with oxygen is described in the section on nitrates.

Describe another method of producing the red fumes.

427. Repeat the experiment of the last paragraph, placing the coin and acid in a small vial or test-tube, instead of a saucer, and collect the nitric oxide produced, as

shown in the figure. The collection should not be commenced until a colorless gas is produced. It will be best to fill the vial to only two-thirds of its capacity. Then lift it from the



bowl, and let the remaining water run out. The air will immediately rush in and change the colorless nitric oxide to red vapors of the peroxide of nitrogen.

How does nitric acid act on tin?

428. OXIDATION WITHOUT SOLUTION.—

Nitric acid oxidizes tin and antimony but does not dissolve them. The experiment will be best made with tin-foil. After the action of the acid, it will be found converted into a white powder. Gold and platinum are neither dissolved nor oxidized by nitric acid.

How may combustion be effected by nitric acid?

429. COMBUSTION BY NITRIC ACID.—As nitric acid contains much oxygen, combustion by its means would seem to be a very probable result. To

prove that it has this effect, boil strong nitric acid in a test-tube, the mouth of which is filled with nair. As the vapors pass through, they will cause it to smoke, and, if the acid is sufficiently strong, produce ignition.



Describe the experiment with phosphorus?

430. COMBUSTION OF PHOSPHORUS.—Phosphorus is readily ignited by throwing it upon nitric acid. If



the acid is not very strong, it must be previously heated. Particles of phosphorus scarcely larger than mustard seed should be used in this experiment.

PHOSPHORUS.

What is phosphorus? Where does it occur?

431. DESCRIPTION.—Phosphorus is a wax-like, and nearly colorless solid, readily ignited by heat or friction.* It forms part of the mineral *apatite*, which is a phosphate of lime. Bones also contain it in large proportion. It is never found uncombined.

How is it prepared?

432. PREPARATION.—Phosphorus is made from bones. These are composed,

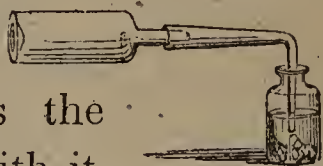
* When phosphorus is cut, it should always be under water, and every particle not used should be immediately returned to a bottle containing water.

principally, of gelatine and phosphate of lime. The individual constituents are gelatine, lime, oxygen and phosphorus. To obtain the phosphorus, all the rest are to be first removed. Fire removes the gelatine, oil of vitriol the lime, and charcoal the oxygen.

Give the complete process.

433. The bones having been previously burned, the ground ash is mixed with dilute sulphuric acid and water, and, after several hours, filtered. Sulphuric acid unites with the lime, forming an insoluble sulphate, and at the same time sets the phosphoric acid at liberty. The solution containing phosphoric acid is then mixed with

charcoal, and heated in an earthen or iron retort. The carbon takes the



oxygen, and passes out of the retort with it, as gaseous carbonic oxide. The phosphorus which is left, being vaporized by the heat, is also expelled, but is reconverted into solid phosphorus by the cold water into which it passes. The figure will give some idea of the arrangement. The neck of the earthen retort passes into a copper tube, which leads into water. The gas produced by the process bubbles through the water and escapes, while the phosphorus is hardened by it and remains. The mass thus obtained is melted under water and run into moulds.

What is phosphorescence?

434. PHOSPHORESCENCE.—This term is applied to the luminous appearance of seawater when agitated, and to other faint light unaccompanied by perceptible heat. It is observed when an ordinary friction match is rubbed upon the hand in the dark. The light is owing to a slow

combustion of phosphorous, which takes place without kindling. The product of the combustion, is a white powder, called phosphorous acid, which soon becomes liquid, by absorbing moisture from the air.

How may a harmless fire be produced? 435. A HARMLESS FIRE.—By agitating phosphorus with ether, a small portion of the former substance is dissolved. This solution, if rubbed upon the face and hands, makes them luminous, in the dark. This is another case of phosphorescence. A piece of phosphorus of the size of a pea is amply sufficient for the experiment.

How may phosphorus be burned under water? 436. COMBUSTION UNDER WATER.—Phosphorus may be burned under water by the help of substances rich in oxygen. Chlorate of potassa is such a substance. Place a few scales of this salt, and a bit of phosphorous of the size of a pea, at the bottom of a wine glass previously filled with water. Partially fill the bowl of a pipe with oil of vitriol, and drop it in small portions on the mixture, bringing the pipe stem, each time, close to the bottom of the glass. As soon as the stronger acid is applied, chloric acid, containing much oxygen, is liberated and decomposed, and the phosphorus inflamed. A similar combustion of phosphorus, by means of nitric acid has already been described.



What is said of friction matches? 437. FRICTION MATCHES.—Ordinary phosphorus is too inflammable to be employed in the manufacture of friction matches. By heating it under carbonic acid for a long time, it becomes changed in color, and also less fusible and in-

flammable. In this form of *red phosphorus*, it is used in the manufacture of friction matches.

ARSENIC.

Why is arsenic introduced among the metalloids?

438. DESCRIPTION.—Arsenic is a grey substance, of metallic lustre, and for this reason commonly classed among the metals. On the other hand, in view of the compounds which it forms, and especially in view of the fact that its oxygen compounds are acids, and not oxides, it is more properly classed among the metalloids. Its analogies to phosphorus are most striking, and it is for this reason here introduced, in immediate connection with that element.

In what respects do phosphorus and arsenic resemble each other?

439. ANALOGIES TO PHOSPHORUS.—Arsenic unites with oxygen in the same proportions as phosphorus, forming similar acids. These in turn form salts resembling each other most perfectly in external appearance and in crystalline form. It also combines with three atoms of hydrogen to form arseniuretted hydrogen, a gas analogous to phosphuretted hydrogen, to be hereafter described. Of the two principal oxygen compounds of phosphorus, the higher or phosphoric acid is the more important, and was therefore more particularly considered. On the other hand, the lower or arsenious acid is the more important of the acids of arsenic.

How is arsenic prepared?

440. PREPARATION.—Metallic arsenic is found native It may also be prepared

from arsenious acid, by heating with a large proportion of carbon, as in the case of phosphorus, before described.

Beside mixing with carbon, it is best, also, to cover with the same material, and heat from above, downwards. The metal passes off as vapor, and condenses in the cooler part of the tube, or other vessel in which the experiment is performed, as a steel grey incrustation.



ARSENIOUS ACID.

What are the properties of arsenious acid?

441. RATSBALE.—The ordinary white arsenic of the shops, also known as *ratsbane*, is a white and nearly insoluble substance, possessed of a slightly sweetish taste. It is not properly arsenic, but arsenious acid. It contains three atoms of oxygen to one of metal. Although sweet, it is called an acid because it possesses the chemical characteristic of an acid, viz: the capacity of uniting with bases to form salts.

How is it prepared?

442. PRÉPARATION.—Arsenious acid is prepared from metallic sulphurets, many of which contain a certain proportion of arsenic, by roasting in the air, and thus burning out their arsenic in the form of arsenious acid. The fumes are condensed in high chimneys, from which the incrustation of the solid acid is afterward removed. Mispickel, which is a double sulphuret of iron and arsenic, and certain ores of nickel and cobalt, are much employed for the production of arsenious acid.

*What is said
of arsenic as
a poison?*

443. POISONOUS PROPERTIES OF ARSENIC.

White arsenic or arsenious acid is a fearful poison, and more frequently employed than any other substance, for the destruction of life. But its detection, and the entire demonstration of its presence in the body, after death, or in materials which have previously been ejected from the stomach, is certain.

*What is said
of its detec-
tion?*

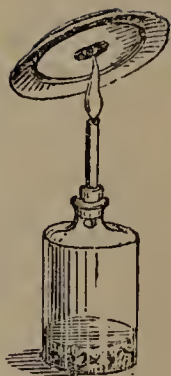
444. No one but a professional chemist should undertake such an investigation, involving, as it does, the issues of life and death. No one else, indeed, can, be qualified to guard, with certainty, against the presence of arsenic in the chemicals which are used in the process, or in other respects, to bring the inquiry to that point of absolute demonstration, which is always required in judicial investigations. But the methods of detection, being simple, and a subject of interesting and instructive experiment to the student, will be briefly described in the paragraphs which follow. Many other compounds of arsenic, beside arsenious acid, are highly poisonous.

*How arsenic is
detected?*

445. DETECTION OF ARSENIC.—If a few drops of a solution of chloride of arsenic* be added to the liquid from which hydrogen is being evolved from a vial, by the ordinary process, the nascent hydrogen decomposes the chloride of arsenic and carries off the metal in the form of a gas. On subsequently kindling the hydrogen jet and bringing

* Such a solution is prepared by dissolving white arsenic in hydrochloric acid.

down upon it a cold white surface, like that of a plate or saucer, the metal is again given up, and reveals itself as a brownish black and highly lustrous stain. The process may be conducted in an ordinary vial, to which a pipe stem, or glass tube has been fitted, by the method before described. The above method



of detection is called Marsh's test. In a case of suspected murder by poison, the moment of the introduction of the pure porcelain into the flame, becomes one of the most intense interest. The gathering stain is at once the emblem of guilt and sentence of ignominious death.

Explain the above process. 446. EXPLANATION.—The decomposition of arsenious acid by hydrogen, in the above experiment, and the reason of the deposition of the metallic mirror, still remains to be explained. The nascent hydrogen affects the decomposition of the acid by a double action; on the one hand uniting with the metal to form arseniuretted hydrogen, which escapes, and on the other hand, with its chlorine to form hydrochloric acid, which remains behind. The mirror of metal is deposited upon the plate or saucer, because the introduction of the cold body into the flame, so lowers its temperature that the metal itself cannot burn. If the jet of gas is left to burn without interference, both of its constituents are consumed together, and the flame assumes a blue color, from the burning arsenic.

How are arsenic and antimony stains distinguished?

447. DISTINCTION BETWEEN ARSENIC AND ANTIMONY STAINS.—If in testing for arsenic, by the method above described, a metallic spot is obtained, the evidence of the presence of arsenic is not entirely conclusive. A solution of antimony, if substituted for arsenic in the experiment, will give rise to the production of somewhat similar stains. But the experimenter will find, on comparing the two kinds of spots, that they are of quite different appearance. Those of antimony are of deeper black, and fainter lustre. Again, those of arsenic are much more readily removed by heat. “Chloride of soda,” is a still more conclusive means of distinguishing them. A solution of this substance will dissolve the arsenic stains, while it leaves those of antimony unaffected. The “chloride of soda,” to be used in the experiment, is prepared by adding an excess of carbonate of soda to a solution of “chloride of lime,” and then filtering the liquid.

Mention some additional tests for arsenic?

448. ADDITIONAL TESTS FOR ARSENIC.—

A second test has already been given in the paragraph on the preparation of metallic arsenic, to which the student is referred. The formation of a yellow precipitate, on the addition of hydro-sulphuric acid to a solution, also renders it highly probable that arsenic is present. If on drying the precipitate, and heating it with a mixture of cyanide of potassium and carbonate of soda, a metallic mirror is obtained, the inference of the presence of arsenic is confirmed. The process is to be conducted as directed in paragraph 440. In this exper-

iment, the cyanide of potassium has the effect of retaining the sulphur, while it allows the volatile arsenic to pass and deposit above.

*What is said
of the garlic
odor?*

449. Still another evidence of the presence of arsenic, is afforded in the characteristic garlic odor which is emitted by the flame produced by burning arsenic, in the experiment previously described, called Marsh's test. The same odor is also obtained on sprinkling a little arsenious acid upon burning charcoal.

*Mention the
preparations
for the ar-
senic test?*

450. PREPARATIONS FOR THE ARSENIC TEST.—Before proceeding with the chemical experiments for the detection of arsenic, some preliminary labor is commonly required, to bring the material to be tested into proper form. It commonly consists of matters which have been ejected from the stomach, or of the contents of the stomach itself. If the student wishes to begin at this point in his experiments, he may add a small portion of arsenic to some bread and water and proceed with this paste in his investigation. This mixture is to be diluted with water and saturated with chlorine, as in the process for preparing a solution of this gas. Chlorine has the effect of destroying a certain portion of the organic matter, and rendering the rest flocculent, so that the liquid may be easily separated from it by filtration. It also brings the arsenic perfectly into solution, as a chloride. This solution is then filtered and treated as directed in the preceding paragraphs.



*What is the
antidote for
arsenic?*

451. ANTIDOTE TO ARSENIC.—The hydrated sesquioxide of iron is regarded as the best antidote to arsenic. (See Oxides.)

Its action depends on the formation of a compound with the poison in the stomach, which is insoluble and therefore inactive. Milk, sugar, and white of eggs are also given with advantage, as in most other cases of poisoning.

*What is said
of the arsenic
eaters of Aus-
tria?*

452. ARSENIC EATERS OF AUSTRIA.—

In the mountainous portions of Austria, bordering on Hungary, the peasantry are given to the strange habit of eating arsenic. It is said to impart a fresh, healthy appearance to the skin, and also to make respiration freer when ascending mountains. Those who indulge in its use commence with half a grain, and gradually increase the dose to four grains. If this habit is regularly indulged, its injurious effects are said to be long retarded. But as soon as the dose is suspended, the symptoms of poisoning by arsenic immediately manifest themselves.

CARBON.

*Describe the
different
forms of car-
bon.*

453. DESCRIPTION.—Carbon in the form of coal, is a black, brittle solid. As plumbago and coke, it is grey, with metallic lustre; as the diamond, it is transparent, and the hardest of known substances. Plumbago is commonly called *black lead*, but it contains no lead whatever. The figure in the margin represents the more common crystalline form of the diamond.



*Where does
carbon occur?*

454. OCCURRENCE.—In the form of bituminous and anthracite coals, carbon exists in immense quantities, buried in the earth, in various countries; as graphite or plumbago, it is also quite a common mineral; as the diamond, it is the rarest of all gems. It is one of the elements in limestones, marbles and chalk, which are all carbonate of lime. It forms nearly one half of all dried vegetable matter, and more than half of all dried animal matter. One twenty-five hundredth of the air, also, is carbonic acid, of which carbon is a constituent.

*Illustrate the
preparation
of charcoal.*

455. CHARCOAL.—The preparation of charcoal, one of the forms of carbon, may be illustrated by heating a small portion of wood or cork in a test-tube. The other constituents of the wood, and part of the carbon, are converted into water, gases, and tar, and the largest part of the carbon remains behind in the form of charcoal.



*How is char-
coal made?*

456. PREPARATION.—In quantity, it is commonly made by burning wood in large heaps, previously covered with earth and sod. It is necessary to admit a little air, through openings in the heap, to maintain a partial combustion. If too much air is admitted, the wood is entirely consumed and no charcoal is produced. Coke is made from bituminous coal by a similar process, and is also obtained as a residue in the manufacture of coal gas.

*How is lamp
black made?*

457. LAMP BLACK.—Lamp black, still another form of carbon, is made by conducting the smoke of rosin into chambers constructed for the purpose. It consists of unburned particles of carbon. It is used, extensively, as a pigment. *Bone black* is made by heating bones in closed vessels. It is a sort of charcoal produced from the gelatine of the bones.

*Describe the
purifying
properties of
charcoal.*

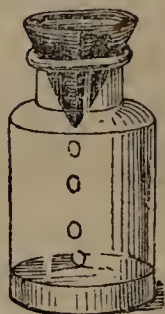
458. PURIFYING PROPERTIES OF CHARCOAL.—Charcoal absorbs gases, and retains them in its pores, in large quantities. Tainted meat, and musty grain, intimately mixed with it, become sweet. The charcoal has removed the unpleasant gases, proceeding from them. The absorbent power of charcoal may be illustrated, by holding a paper moistened with ammonia, in a vial, until the air within it has acquired a strong ammoniacal odor. On afterward introducing some powdered charcoal and shaking the vial, the odor will be removed.

*Illustrate the
preservative
properties of
charcoal?*

459. PRESERVATIVE PROPERTIES OF CHARCOAL.—Charcoal may be used as a preventive, as well as a corrective of decay. Posts, if charred at the bottom before they are set, are rendered more durable. Water will keep longer in charred vessels than in those which have not thus been prepared. The decay of meats and vegetables is retarded by packing them in charcoal. Charcoal is itself, one of the most unchangeable of substances. Wheat and rye charred at Herculaneum 1800 years ago, still retain their perfect shape.

Describe its decolorizing power.

460. DECOLORIZING EFFECTS OF CHARCOAL.—Charcoal has, also, the effect of removing coloring matters, and bitter and astringent flavors from liquids. Thus, ale and porter lose both color and flavor by being filtered through charcoal. Sugar refiners take advantage of this property in decolorizing their brown syrups. Animal charcoal or bone black is best adapted to these uses. As an illustration of the decolorizing effect of charcoal, let water colored with a few drops of ink be filtered through bone black. The color will be found to disappear in the process.



What is said of the combustion of carbon?

461. COMBUSTION OF CARBON.—All of the forms of Carbon are combustible. The combustion of charcoal in air is a familiar fact. Its combustion in oxygen has been already shown. The diamond and plumbago will also burn in a vial of oxygen gas, if first intensely heated. The product of their combustion, is precisely the same as that of charcoal. From the carbonic acid, which is produced in the combustion, the carbon may be obtained in the form of lamp black. The nature of the diamond is thus conclusively established.



How does charcoal reduce metals?

462. REDUCTION OF ORES BY CHARCOAL. The affinity of carbon for oxygen, at a high temperature, is very intense. It deprives most ores of their oxygen, and converts them into metals. An agent which thus produces metals from their compounds, is called a reducing agent, and

the process is called *reduction*. Gaseous carbonic oxide has the same effect as carbon, because the affinity of its carbon for oxygen is only partially satisfied. In the process of reduction, these reducing agents are themselves converted into carbonic acid, by the oxygen with which they combine. Hydrogen gas, in consequence of its strong affinity for oxygen, is also a powerful reducing agent: The reducing power of carbon may be illustrated by sprinkling a little litharge on ignited charcoal, and blowing upon it at the same time, to maintain its heat. The litharge or oxide of lead will thus be partially converted into globules of metal.

CARBONIC ACID.

463. DESCRIPTION.—Carbonic acid is a colorless gas, without much taste or smell, and about one and a half times as heavy as air. Other properties are illustrated in the experiments which follow. This gas is found in many mineral waters, and frequently escapes from fissures in the earth. It is a constituent of all limestones and shells, and forms $\frac{1}{2500}$ part of the atmosphere. It is exhaled from the lungs of all animals, and is a product of the combustion of coal and wood.

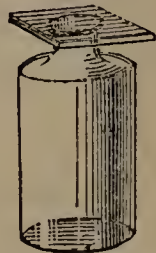
*What is carbonic acid?
Where does it occur?*

464. PREPARATION.—Carbonic acid may be prepared by burning charcoal in oxygen gas, as directed in paragraph 339. Or it may be made by hanging a lighted candle, as long as it will burn, in a bottle filled with ordinary air. In this

case, the carbon of the candle is converted into carbonic acid, by the oxygen of the air. But neither of these methods give the unmixed gas, and that which follows is therefore to be preferred.

Give the second method of preparing it.

465. ANOTHER METHOD.—Pour a tea-spoonful of muriatic acid into a large-mouthed half-pint vial, and then add bits of marble, chalk, or carbonate of soda until effervescence ceases. The vial will then be filled with carbonic acid.



Explain the above process.

466. EXPLANATION.—Chalk and marble are both carbonate of lime. As soon as they are dropped into muriatic acid, this stronger acid combines with the lime and retains it, setting the carbonic acid at liberty in the form of a gas. The gas as it accumulates, expels the air from the vial and completely fills it. It is obvious that in this method we do not make carbonic acid, but use that which nature has already made for us and imprisoned in the marble.

Describe another method of preparation.

467. For most of the experiments that follow, the second simple method of collection is sufficient, and the gas need not be transferred to another vessel. When it is desired to obtain it separate from the materials from which it is produced, the apparatus represented in the figure may be employed.

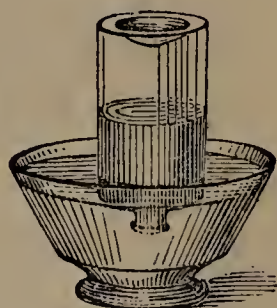


How are carbonated waters made?

468. CARBONATED WATERS.

Water absorbs its own volume of carbonic acid and thereby acquires an acid taste.

The so called "soda water" or "mineral water," is prepared by confining water in a strong metallic vessel, and forcing into it gaseous carbonic acid, by means of a forcing-pump. The increased quantity which it is thus made to absorb is in precise proportion to the pressure employed. Neither of the above names give a correct notion of the nature of the effervescent drink referred to. It is simply carbonated water, to which soda is sometimes added.



469. The absorption of carbonic acid by water may be shown, like that of chlorine, by the method illustrated in the figure. It may also be shown by pouring a gill of water into a half-pint vial of carbonic acid and then shaking it. The palm of the hand being pressed closely upon the mouth of the vial, the flesh will be more or less drawn in, to take the place of the gas absorbed. The vial may be supported by this attachment.

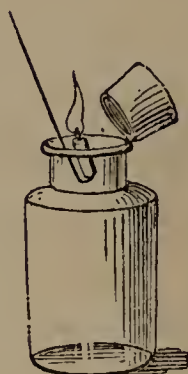
470. EFFERVESCENT DRINKS.—Cham-
What is said
of effervescing
drinks? paigne, sparkling beer and mead, congress
 water, and similar drinks, owe their effervescent qualities to this gas held in solution. On exposure to the air, the gas gradually escapes, and the liquids become insipid to the taste. The air enters and takes its place, expelling sixty or seventy times its own volume of gas. This effect may be hastened by striking, with the hollowed palm of the hand, upon the top of a glass partly filled with one of these liquids; thereby compressing the air, and forcing it to enter rapidly.

The carbonic acid immediately escapes with renewed and rapid effervescence.

471. FLAME EXTINGUISHED

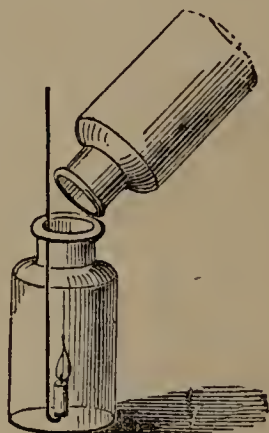
What effect has carbonic acid on flame?

BY CARBONIC ACID.—Lower a lighted taper, candle, or splinter of wood into a vial of carbonic acid, prepared as before directed. The flame will be immediately extinguished, as if it had been dipped in water.



Give another method of performing the experiment.

472. Or the same experiment may be performed by pouring the gas into a vial, at the bottom of which is a bit of lighted candle. Nothing will be seen to flow from one vessel into the other, but the effect will be the same as before.



Of what use to plants is carbonic acid?

473. CARBONIC ACID IS FOOD FOR PLANTS.—Carbonic acid is one of the principal

elements of the food of plants. The leaves absorb it from the air, and the roots from the earth, and convert it into wood and fruit. The subject is further considered in the latter part of this work.

What is the effect of carbonic acid on animals?

474. IT IS POISON FOR ANIMALS.—Water impregnated with carbonic acid is a healthful drink; but the same gas, when taken into the lungs, produces death. It operates negatively, by excluding the air, and also positively, as a poison. Being heavier than the air, lakes of this gas sometimes collect in the bottom of caverns. There is a grotto of this kind in Italy, called

the Grotto del Cane, or dog's grotto. A man walking into it is safe, but his dog, whose head is below the surface of the gaseous lake, is immediately suffocated. Baths of carbonic acid have recently been employed, with advantage, in the treatment of rheumatism and other similar affections, and in cases of enfeebled vision.

How is carbonic acid removed from wells? 475. HOW REMOVED FROM WELLS.—Carbonic acid often collects in the bottom of wells, and occasions danger, and sometimes death, to workmen employed in cleaning them. A candle previously lowered into the well will indicate the danger, if it exist. The flame will burn less brilliantly, or be entirely extinguished, if much of the gas is present. By repeatedly lowering pans of recently heated charcoal into the well, and drawing them up again, the gas will be absorbed and removed. The charcoal is first heated, to increase its absorbing power. In this condition it absorbs thirty-five times its own bulk of gas.

How does burning charcoal cause fatal accidents? 476. CHARCOAL FIRES IN CLOSE ROOMS. Fatal accidents not unfrequently occur from inhaling the fumes of charcoal burned in close unventilated rooms. These fumes consist of mingled carbonic acid and carbonic oxide. The latter gas will be hereafter described.

How may carbonic acid be solidified? 477. SOLIDIFICATION OF CARBONIC ACID. One of the most interesting of all chemical experiments, is the solidification of carbonic acid. By combined cold and pressure, this transparent gas, which, under ordinary circumstances, is so

thin that the hand, passed through it, does not recognize its presence, can be converted into a solid snow. This is done by bringing into a strong iron cylinder, connected by a tube with a second similar receptacle, the material for making more of the gas than there is room for in the two vessels. The cylinders being closed, and the gas produced by the agitation of the materials, it is evident that they must burst, or the gas must pack itself away in some more condensed form. The second vessel is surrounded by ice, and kept extremely cold, during the process. In this colder vessel the gas assumes a liquid form. Being removed in this condition, one portion of the liquid evaporates so rapidly as to freeze the rest. An explosive expansion of the liquid into gas would naturally be anticipated, but this does not occur. The materials used in the process are sulphuric acid and carbonate of soda.

How is carbonic oxide formed?

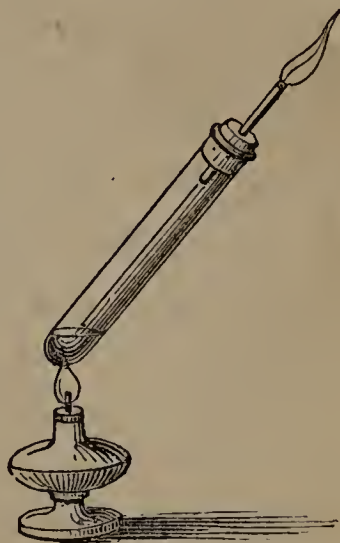
478. CARBONIC OXIDE.—When carbonic acid is passed through hot coals, it loses half of its oxygen and becomes carbonic oxide. This takes place in coal fires. The coal in the lower part of the grate, where air is plenty, receives its full supply of oxygen and becomes carbonic acid. The hot coals above, where the supply of air is limited, take half of the oxygen from the carbonic acid, and reduce it to this oxide, converting themselves partially into carbonic oxide at the same time. The new gas passes on to the top of the fire, and there, where air is again abundant, it burns with a blue flame, and reconverts itself into carbonic acid. This gas is much more poisonous than carbonic

acid, and is one source of the danger which arises from open fires in close rooms. One-two-hundredth of it makes the air, if inhaled for any considerable time, a fatal poison.

479. COMBUSTION OF CARBONIC OXIDE.

How is carbonic oxide best prepared?

For small experiments, the gas is best prepared by covering a half tea-spoonful of oxalic acid* with oil of vitriol, and heating them together in a test-tube. The gas, on being kindled at the mouth of the tube, burns with a beautiful blue flame. The experiment is rendered more striking by producing a jet, as represented in the figure. The gas thus obtained is really a mixture of carbonic oxide with carbonic acid, but the admixture does not materially affect the experiment.



Explain the formation of carbonic oxide.

480. EXPLANATION.—Each molecule of oxalic acid contains carbon, oxygen, and hydrogen, in the proportion to form one molecule each, of water, carbonic oxide, and carbonic acid. Through the agency of sulphuric acid, this decomposition is effected. The water remains with the acid while the gases are evolved.

What is the effect on metallic oxides?

481. IT PRODUCES METALS FROM OXIDES. With the help of a high temperature, carbonic oxide takes oxygen from oxides, and converts them into metals. It contains oxygen

* This acid has the appearance of a salt, and is poisonous.

already, but its chemical appetite is only half satisfied with that element. It is this gas, produced in the fire, as before described, which converts iron ores into metal, in the smelting furnace. It is itself converted into carbonic acid at the same time.

SILICON.

What is silicon?

482. DESCRIPTION.—Silicon is a dark gray substance, possessed of metallic lustre, but classed with the metalloids because it resembles them in its compounds. It is also called silicium. It is prepared from silica, by the method hereafter described for the production of calcium from lime.

What is silica?

483. SILICIC ACID OR SILICA.—Quartz or rock crystal is nearly pure silica. Seashand, opal, jasper, agate, cornelian, and chalcedony, are other forms of the same substance. It also forms part of a very abundant class of rocks, called *silicates*, and probably constitutes one-sixth of the mass of the earth.

How can silica be made soluble?

484. SOLUBLE SILICA.—Silica may be dissolved in water, by first fusing it with a large proportion of potash. On then adding acid, to neutralize the potash, the silica precipitates in the form a jelly. By this circuitous process, the most gritty sand is converted into a soft jelly. A singular application of this rock-jelly, in the adulteration of butter, has recently been detected in England. Dissolved silica also occurs in nature, and hardens into agates, onyx, and other precious stones.

*What is the
cause of pet-
rification?*

485. PETRIFICATIONS.—As wood wastes away in certain silicious waters, the particles of silica take, one by one, the place of the departing atoms, and thus copy the wood in stone. Such copies are called petrifications.

BORON.

*What is bo-
ron?*

486. DESCRIPTION.—Boron is a brown powder, never seen except in the chemists laboratory, and of no practical value. It occurs in nature, combined with other elements, as borax and boracic acid.

*How is bora-
cic acid form-
ed?*

487. BORACIC ACID.—This acid is commonly seen in the form of white pearly scales. It exhales with volcanic vapors which issue from the earth in Tuscany. These vapors are condensed in water, and the solid acid is obtained by evaporating the solution. The acid is used like borax, as a flux. It is bitter, rather than sour, to the taste, but is called an acid because it forms salts.

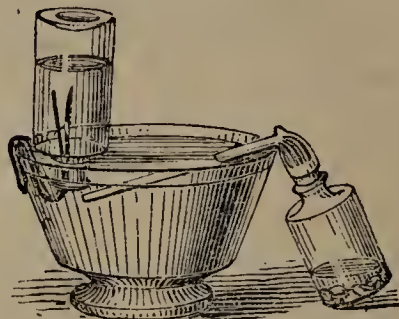
HYDROGEN.

*What is hy-
drogen?
Where does it
occur?*

488. DESCRIPTION AND OCCURRENCE.—Hydrogen is a colorless gas, about one fifteenth as heavy as the air. It is of such extreme tenuity, that it may be blown through gold leaf and kindled on the opposite side. One-ninth part of the ocean, and the same proportion of all water in existence, is hydrogen gas. It enters,

also, largely into the composition of all animal and vegetable matter, and forms the basis of most liquids.

489. PREPARATION.—Introduce a few bits of iron or zinc into a vial one-third filled with water. Add a tea-spoon-full or more of common sulphuric acid, and attach to the vial a bent tube or a clay pipe, as represented in the figure. The evolution of the gas immediately commences. The first portions, which contain an admixture of air, are allowed to escape; the pipe-stem is then brought under the mouth of the vial, and the gas collected.*



590. EXPLANATION.—Water is composed of oxygen and hydrogen gases. Each would be a gas, but for the other, which holds it in the liquid form. In the above process for preparing hydrogen, the zinc is, as it were, the ransom paid for its liberation. The oxygen combines with the zinc and the hydrogen escapes.

491. Pure water will not suffice in the process. It must contain acid, to unite with the oxide of zinc, as fast as formed. The presence of an acid, for which the oxide has great affinity, seems to stimulate its formation. It may,

Describe the method of preparing it?

Explain the formation of hydrogen?

What purpose is served by the acid?

* When a taper can be applied at the mouth of the pipe-stem without explosion, it may be certainly known that an unmixed gas is in process of evolution. A cloth should be thrown over the vial and this test made before commencing the collection. The connection of the apparatus in the above experiment is made with a paper stopper, formed on a bit of pipe-stem or glass tube.

indeed, be regarded as a general law, that the presence of acids promotes the formation of oxides, and *vice versa*.

Give another method of preparing it. 492. ANOTHER METHOD.—Hydrogen may also be made by passing steam through a heated gun-barrel containing bits of iron. Bundles of knitting needles are commonly employed for the purpose. The steam leaves its oxygen combined with the iron, and escapes as hydrogen gas.

What is produced by the combustion of hydrogen? 493. COMBUSTION OF HYDROGEN.—Bring a dry, cold tumbler, over a burning jet of hydrogen. The vessel will soon become moistened on the interior. The water thus produced, is a result of the combination of hydrogen with oxygen of the air. But for the cold surface, with which it is brought into contact, it would have escaped into the air as vapor. The composition of water was shown in Part I., (§ 277,) by galvanic decomposition. It is here demonstrated by combining its elements and thus reproducing it. Water is also formed in the combustion of any substance containing hydrogen as one of its constituents. The above experiment may therefore be made with a lighted lamp or candle, as well as with the jet of pure hydrogen.

How is an explosive mixture prepared? 494. EXPLOSION OF MIXED OXYGEN AND HYDROGEN.—Allow oxygen to flow into an inverted vial, as directed in paragraph 330, until it is one-third full. Fill it up with hydrogen, collected as shown in Par. 489. Cork the vial under water. It is now filled with an explosive mixture, which may be fired by the



application of a taper. To secure against accident, the precaution should invariably be observed of winding the vial with a towel, before the discharge.

Why does this mixture explode?

495. EXPLANATION.—The explosion results from the fact that all of the hydrogen in the vial burns at once, causing great heat, and sudden expansion of vapor. The combustion is thus simultaneous, because oxygen, the supporter of combustion, is present at every point. When, on the other hand a jet of hydrogen is kindled, no explosion occurs, because the combination is gradual. Combustible hydrogen meets with oxygen in this case, only on the surface of the jet.

Describe the hydrogen gun, and the method of charging it.

496. THE HYDROGEN GUN.—The experiment for the explosion of mixed hydrogen and oxygen gases, may be made in a strong tin tube, provided with a vent near the closed end. Such a tube, about an inch in diameter, and eight inches in length, is called the *hydrogen gun*. In loading it, the vent is stopped with wax, the tube filled with water, and the gases, previously mixed in the right proportion, poured upward into it, as indicated in the figure. The gun, being thus loaded, is tightly corked, under water, and afterward fired at the vent. The explosion is sufficient to expel the cork with violence, accompanied by a loud report. The vial from which the tube is loaded must not be too large, or it will not be practicable to turn it and pour upward, as desired. This difficulty



may also be obviated, by the substitution of a water-pail, for the bowl represented in the figure.

497. CHARGE OF AIR AND HYDROGEN.

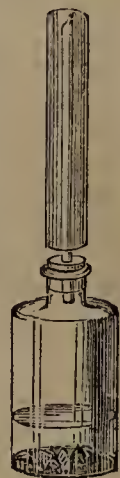
Describe another explosive mixture.

As air contains uncombined oxygen, a mixture of air and hydrogen also forms an explosive mixture. But, as air is only one-fifth oxygen, five times as much of it must be used; in other words, five parts of air are required, for every two parts of hydrogen. To make the mixture, hydrogen may be led, as before, into an inverted vial a little more than two-thirds full of air. The exact proportion is not essential in this, or any similar case of explosive mixture.

498. A SIMPLER METHOD.—A simpler

Give a simpler method of loading the gun.

method of loading the gun, or charging the vial with the explosive mixture, is to invert it over a jet of hydrogen, as represented in the figure. The pipe-stem, or tube, which conveys the gas, is previously wound with paper, till it occupies about two-thirds of the inner space of the gun. Escaping hydrogen fills the remainder. On withdrawing the tube, air enters to take its place, and the gun is thus charged with mixed air and hydrogen, in the right proportions. It is then corked and fired. This experiment may also be made with a test-tube, discharging it at the mouth. Explosions with mixed air and hydrogen, are, of course, less violent than where pure oxygen is used instead of the diluted oxygen of the air.



Does hydrogen support combustion?

499. HYDROGEN WILL NOT SUPPORT COMBUSTION.—Flame is extinguished in hy-

drogen, as it would be in water. Re-charge the gas bottle, if necessary, and hang a second large-mouthed vial above it, as represented in the figure. After a few minutes, it may be presumed that the upper vial is filled with hydrogen. Apply a lighted match to its mouth, and the gas will inflame, and continue to burn with a faint light. Introduce a second taper, as represented in the figure. It will be kindled at the mouth of the bottle, and again extinguished above. The match is extinguished, because, a little above the mouth of the vial, there is no oxygen to support the combustion of the carbon and hydrogen of which it is composed.



Describe the preparation of hydrogen by sodium.

500. HYDROGEN MADE BY THE METAL SODIUM.—Another very beautiful, but more expensive method of making hydrogen gas, is as follows. Fasten a piece of metallic sodium, of the size of a pepper-corn, upon the end of a wire, and thrust it suddenly under the end of a test-tube filled with water, and held very near the surface, as represented in the figure. The metal melts as soon as it touches the water, and rises to the top of the tube. Hydrogen is immediately formed, and displaces the water, filling the tube rapidly with the liberated gas.



Explain the process.

501. EXPLANATION.—Sufficient heat is evolved by the action of sodium on water to fuse it at once. The metal is lighter than water, and therefore rises to the top of the tube. At this

point the chemical process begins. Sodium has the most intense affinity for oxygen, and therefore combines with this element of the water, setting its hydrogen at liberty. No acid is required as in the case of zinc. Metallic potassium may also be used in this experiment. To avoid its ignition by contact with the water, it is to be wrapped in paper, and the twisted end of the wrapper used as a holder, with which to thrust it under the mouth of the tube.

WATER.

*Of what is
water com-
posed?*

502. COMPOSITION.—Many important properties of water have already been illustrated in the chapter on Vaporization. Others will be mentioned below. It is composed of oxygen and hydrogen, as has already been proved both by analysis and synthesis. These gases are condensed in combination to about $\frac{1}{2000}$ of their original volume. It remains to show how the exact proportion in which they enter into the composition of water is ascertained.

*Describe the
method by gal-
vanic decom-
position.*

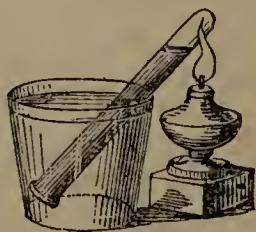
503. FIRST METHOD OF PROOF.—One method is to decompose water by the galvanic process, and collect and weigh the gases obtained. The oxygen is found to weigh eight times as much as the hydrogen. Water is thus shown to be composed of eight parts of oxygen, by weight, to one part of hydrogen. In other words, nine pounds of water contain eight pounds of oxygen and one pound of hydrogen.

Show how composition by weight may be calculated from measure.

504. SECOND METHOD.—Another method is to *measure* the gases obtained by the same method of decomposition. Two measures of hydrogen are thus obtained for every single measure of oxygen. The chemist then proceeds to calculate the relative weight. Knowing beforehand that hydrogen is the lighter gas, weighing but one-sixteenth as much as the same quantity of oxygen, he infers that the double volume obtained in the above experiment, weighs but one-eighth as much as the oxygen obtained in the same decomposition. The result of this indirect process is the same as that stated at the conclusion of the last paragraph.

Describe the third method.

505. THIRD METHOD.—A third method consists in the reproduction of water from mixed hydrogen and oxygen, observing at the same time the quantities in which they combine. This may be readily effected in a test-tube. The gases being introduced into the tube in about the right proportion, and in small quantity, its extremity is then intensely heated. A slight explosion and combination of the gases is the result, and the water rises to take their place, mingling with the small quantity of water produced in the experiment. Any excess of either gas remains uncombined. Whether this surplus is oxygen or hydrogen, may be readily proved by methods previously given. This excess being subtracted from the quantity of the same gas originally used, shows the proportion in which the combination has occurred



How may the explosion be avoided?

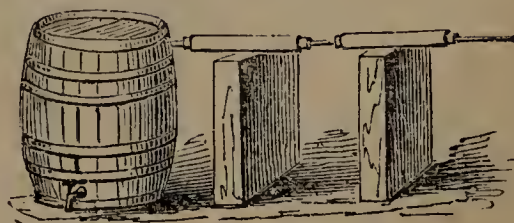
506. The explosion may be avoided, and a gradual combination of the gases effected, by evaporating a few drops of platinum solution in the test-tube, and igniting the residue previous to the commencement of the above experiment. A ball of fine iron wire is then crowded into the end of the tube. The mixture of gases being finally introduced, the least touch of flame upon the end of the tube is sufficient to effect a gradual combination. For an explanation of the agency of platinum in the above experiment, the student is referred to the chapter on metals. The iron wire serves to prevent ignition, and consequent explosion, by appropriating part of the heat produced by the combination of the gases. The form of the experiment last described, is the only one that can be recommended to the student. With the security against explosion which it affords, a test-tube filled with the mixed gases may be submitted to experiment. Where very accurate results are sought, the process must be conducted in a carefully graduated tube. By employing mercury instead of water, the water produced in the experiment may be seen.

Give the method by oxide of copper.

507. FOURTH METHOD.—Still another method is illustrated in the figure. It consists, essentially,

ly, in the production of water from its elements as before; furnishing, at the same time, the means of as-

certaining the proportional weight of the gases which have taken part in its formation. The tube most



distant from the aspirator* is first filled with oxide of copper, and then heated while a current of hydrogen gas is drawn over its surface. The heated hydrogen carries with it the oxygen of the copper, and passes into the second tube, as vapor of water. Here it is retained by potassa, or some substance of similar properties. Both tubes are afterward weighed, and their gain or loss determined by comparison with their weight before the commencement of the process.

*How are the
results calcu-
lated?*

508. The loss of weight in the one tube, expresses the weight of the oxygen which it has furnished for the formation of water ; the gain in the second tube, gives the weight of the water thus formed. The difference of the two, gives the weight of the hydrogen which has been appropriated in its passage, and now makes part of the newly formed water. For every nine grains of water thus produced, it is found that eight grains of oxygen, and one of hydrogen have been consumed. Its precise composition is thus demonstated by another and quite distinct process.

*What is said
of solution?*

509. SOLUTION.—Water is a very general solvent. The disappearance of salt or sugar, in water, is an example.† Transparency is essential to a solution. Where the particles of a solid are distributed throughout a liquid, as when chalk is

* A vessel employed, as in the present instance, to produce a current of air or gas, is called an aspirator.

† Water also dissolves many gases. The ammonia of the shops is prepared by passing gaseous ammonia into water.

stirred with water, it is said to be diffused, instead of dissolved. The solvent action of water plays a most important part in nature, as will be seen in the concluding chapter of this work. The subjects of solution and precipitation, are more fully considered in the chapter on Salts.

What is precipitation?

510. PRECIPITATION.—Where a substance which has been dissolved is re-converted into a solid form, it is said to be *precipitated*. Thus, when air from the lungs is blown through a pipe-stem into lime-water, the lime combines with the carbonic acid from the lungs, and falls to the bottom of the vessel, in the form of solid particles of chalk. The solid thus produced is called a *precipitate*.



What is filtration, and how is it effected?

511. FILTRATION.—Filtration is the separation of a precipitate from the liquid in which it is contained. This is effected by throwing the mixture into a paper cone, which retains the solid, while the liquid passes through its pores. Such a filter is prepared by folding unsized paper into the shape of a quadrant, which is then opened, so as to form a cone, commonly supported in a glass funnel. It is possible, in small experiments to dispense with the funnel, as is done in the figure, and even to use ordinary newspaper in the place of that especially prepared for the purpose.



How may crystals of alum be obtained?

512. CRYSTALLIZATION.—Dissolve half a pound of alum in a pint of boiling water, and hang a cotton cord in the vial. As the water cools, crystals will form on the thread. Bonnet wire may be bent into the shape of baskets, miniature ships, &c., and covered, by this means, with a beautiful crystallization.



Explain the process.

513. EXPLANATION.—Hot water has, for most substances, greater solvent power than cold water. In the case of alum, for example, water slightly warmed will dissolve twice as much as cold water. It follows, that as the hot water becomes cold, part of the alum must become solid again. In so doing, the particles, in obedience to their mutual attraction, arrange themselves in crystals, as described in Chapter III.

What is said of snow crystals?

514. SNOW CRYSTALS.—Snow flakes are always either grouped or single crystals, and their form may often be distinctly seen with the naked eye. They are best observed by catching them upon a hat, or other dark object, and inspecting them in the open air.



What is said of the combinations of water?

515. CHEMICAL COMBINATIONS.—Water unites with both bases and acids, to form *hydrates*. Thus, with lime, it forms hydrate of lime; with sulphuric acid, hydrated sulphuric acid. Most of the oxygen acids, in the form in which we employ them, contain water in a state of combination, and are therefore hydrated

acids. They may also be regarded as salts, of which oxide of hydrogen or water is the base.

*What is said
of water in its
relations to
life?*

516. RELATIONS TO LIFE.—Water forms, by far, the greater part of all animal and vegetable matter, as will be more fully seen in the portion of this work which treats of organic chemistry. To water the leaf of the vegetable and the muscle of the animal owe, in a great degree, their pliancy and freedom of motion. In view of these and other relations to life, the negative properties of water are not the least important. Had it taste or odor, however exquisite, we should soon weary of them. And but for its mild and neutral character, it would irritate the delicate nerves and fibres which it bathes.

*What is the
effect of water
at high tempe-
ratures?*

517. At very high temperatures the vapor of water decomposes many minerals, and expels strong acids from their compounds. Under the stimulating influence of heat, this neutral liquid becomes a chemical agent of extreme energy. Such decompositions as are here referred to, are without doubt, constantly going on beneath the surface of the earth.

COMPOUNDS OF HYDROGEN, WITH CHLORINE, BROMINE, IODINE, FLUORINE, AND SULPHUR.

Under this head are to be described a new series of acids, distinguished by the absence of oxygen, from all which have hitherto been mentioned. The molecules of each, like those of water, are composed of single atoms of their constituents.

They are all gaseous, and are sometimes called *hydroacids*, from the hydrogen which enters into their composition. Their salts are described in Chap. III.

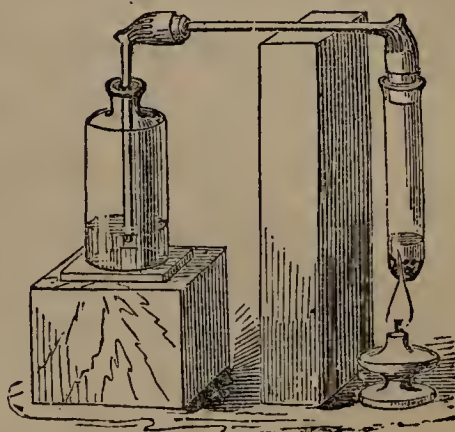
HYDROCHLORIC ACID.

What is hydrochloric acid? What is said of its occurrence? 518. DESCRIPTION.—Hydrochloric acid is a colorless gas, fuming by contact with the air. It sometimes issues from volcanoes, but is, for the most part, an artificial product. Its solution in water is known as muriatic acid.

Describe its preparation. 519. PREPARATION.—Gaseous hydrochloric acid may be produced, like water, by the direct combination of its elements. For this purpose, equal volumes of the two gases are mixed by candle-light or in carefully covered bottles, and then exposed to the direct rays of the sun. The action of the light is so intense, that on throwing a bottle thus filled from shadow into sunlight, it immediately explodes. The explosion is a consequence of the energetic union of the two gases, under the influence of the chemical rays of the sun. The acid produced is at once dissipated in the air. Great caution should be used in this experiment, for even the diffused light of day has been known, in some instances, to occasion explosion.

Describe another mode of preparing it? 520. ANOTHER METHOD.—Hydrochloric acid may also be made from common salt, which furnishes the chlorine, and ordinary hydrated sulphuric acid, which furnishes the hydrogen.

A tea-spoonfull of common salt is introduced into a test-tube with about the same bulk of water. Half as much acid is added, the mixture then gently heated, and the acid gas ied into water, as shown in the figure. Water absorbs, at ordinary temperatures, 480 times its own volume of the gas.



There is no occasion, for the purpose of experiment, to carry on the process till it is thus saturated. A few minutes will suffice to make an acid strong enough to dissolve zinc.

Explain the process.

521. EXPLANATION.—Hydrated sulphuric acid has always a strong tendency to form metallic salts. In this case it takes the metal, sodium, from the common salt, and thereby converts itself into sulphate of soda. At the same time it gives back hydrogen to the salt, in place of its lost sodium, converting it, by the exchange, into hydrochloric acid. The process just described, is the one always employed in the manufacture of hydrochloric acid.

What metals does hydrochloric dissolve?

522. ACTION OF HYDROCHLORIC ACID ON METALS.—Hydrochloric acid dissolves tin and all of the metals which precede it in the chapter upon metals. For tin, a hot and concentrated acid must be employed.

On what does the solution depend?

523. The solution depends on the fact that the metals take chlorine, from the hydrochloric acid, thereby converting themselves into soluble chlorides. The hydrogen then

assumes the gaseous form, and escapes with lively effervescence. An experiment may best be made with zinc, covered with a little dilute acid.

What is aqua regia? 524. AQUA REGIA.—On mixing nitric acid with twice its bulk of strong hydrochloric acid, *aqua regia* is produced; so called, from its regal power over the noble metals. Gold and platinum, which are not effected by either acid alone, dissolve readily in aqua regia. The solvent power of aqua regia depends, as before explained, on the nascent chlorine which it supplies.

What of hydrobromic and hydriodic acids? 525. HYDROBROMIC AND HYDRIODIC ACIDS. These acids are of interest to the chemist only. They resemble hydrochloric acid, in being colorless gases, strongly acid, soluble in water, and capable of dissolving many metals.

HYDROFLUORIC ACID.

What is hydrofluoric acid? 526. DESCRIPTION.—Hydrofluoric acid is a colorless, corrosive gas, acting on glass, and many minerals which other acids do not affect. It condenses into a liquid at the freezing point of water. It is not known to occur ready formed in nature.

How is hydrofluoric acid prepared? 527. PREPARATION.—Hydrofluoric acid is made from a mineral called *fluor spar*, by the same means employed to make hydrochloric acid. On account of its corrosive action on glass, vessels of lead or platinum are employed in the

process. This gas is so poisonous, when inhaled, and its solution so corrosive to the skin, that its preparation, in any considerable quantity, should be left to the experienced chemist.

Explain the process?

528. EXPLANATION.—In the above process, the fluor spar, which is a fluoride of calcium, furnishes the fluorine, and hydrated sulphuric acid, the hydrogen. The remaining constituents unite to form sulphate of lime, which remains in solution.

Give the process for etching glass.

529. ETCHING ON GLASS.—It has already been stated that hydrofluoric acid attacks glass and many minerals. By covering with wax, they may be protected against the corrosion. Advantage is taken of these two facts in etching upon glass. The surface is first slightly warmed and rubbed with beeswax, and then warmed again, to produce an even coating. Figures or letters are then drawn upon the glass, through the wax, with a pen-knife or other pointed instrument. The plate being now exposed for a few minutes to the fumes of hydrofluoric acid, and the wax subsequently removed, is found to be deeply etched. Fumes of hydrofluoric acid for the purpose, are best obtained by placing a half tea-spoonful of pulverized fluor spar in a warm tea-cup, and covering the powder with oil of vitriol. A little ether or potash will be found of use in removing the last portions of wax from the plate.



Explain the above process.

530. EXPLANATION.—As oxygen combines with carbon to form carbonic acid, so

the hydrofluoric acid eats out the silicon of the glass, where it is exposed, and passes off with it, in the form of a new and more complex gas. A solution of the gas may be prepared by the process employed for hydrochloric acid. Bottles of vulcanized India rubber or gutta purcha may be used in keeping the solution

HYDROSULPHURIC ACID.

What is hydrosulphuric acid? 531. DESCRIPTION.—Hydrosulphuric acid is a colorless gas, also known as *sulphuretted hydrogen*. It has a putrid odor and feeble acid properties. Like the rest of the series, it is soluble in water. It occurs in many natural waters, called sulphur springs. It is one of the products of the decomposition of animal matter, and the source of much of the disgusting odor which they emit during putrefaction.

How is it prepared? 532. PREPARATION.—It is made from sulphuret of iron, as hydrochloric acid is made from common salt, and hydrofluoric acid from fluor spar. In the above process, sulphuret of iron furnishes the sulphur, and hydrated sulphuric acid, the hydrogen. The remaining elements unite to form sulphate of iron, which remains in solution. On account of the disgusting smell of the gas, it is best to prepare it only in small quantities.

What effect has it on metals, &c.? 533. DISCOLORATION OF METALS AND PAINTS.—The blackening of silver watches and coins, in the vicinity of sulphur

springs, is an effect of hydrosulphuric acid gas. Its discoloring effect may be illustrated, by pouring a little dilute sulphuric acid upon a few grains of sulphuret of iron, in a tea-cup, and holding a bright moist coin in the fumes. Its effect on paints may be shown by exposing a piece of paper, moistened with solution of sugar of lead, in the same manner. The white paper immediately assumes a dark metallic stain. Paper moistened with a solution of tartar emetic, takes a deep orange hue. This experiment is often varied, by drawing amusing figures on paper with lead solution, and bringing them out by exposure to the gas.

Explain the cause of the change of color.

534. EXPLANATION.—The change of color in each case, is owing to the formation of a metallic sulphide, having a different, and generally a darker color. Zinc is not blackened, because its sulphide happens to be white. For this reason, chemical laboratories and other places where hydrosulphuric acid is likely to be evolved, should be painted with zinc paints, instead of those containing lead.

What is the effect of sulphuretted hydrogen on animals?

535. RELATIONS TO LIFE.—Sulphuretted hydrogen, if inhaled in any considerable quantity, acts as a poison. Caution should therefore be observed in experiments with this gas. The mixture of gases which is given off from recently ignited coal, contains sulphuretted hydrogen acid in large proportion, and owes its deleterious qualities, in considerable part, to this admixture.

AMMONIA.

*What is ammonia?
Where does it occur?*

536. DESCRIPTION.—Ammonia is a colorless gas, of pungent smell, and alkaline properties. It is exhaled from volcanoes, and is a product of the decomposition of all vegetable and animal matter. Its molecule contains one atom of nitrogen to three of hydrogen.

What is said of its production from nitrogen and hydrogen?

537. PRODUCTION FROM ITS ELEMENTS. Although nitrogen and hydrogen gases are the sole elements of ammonia, they cannot, under ordinary circumstances, be made to unite directly and form it. Heat does not stimulate their affinities sufficiently to bring about this result. Electrical sparks passed, for a long time, through a mixture of the gases, cause them to combine to a limited extent.

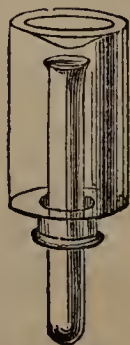
Production from its nascent elements.

538. PRODUCTION FROM NASCENT ELEMENTS.—Iron, at a high temperature, expels hydrogen from ordinary hydrate of potassa, and nitrogen from nitre. If heated with both together, it expels both nitrogen and hydrogen, and the two nascent elements unite, to form ammonia. The experiment may be performed by covering bits of potash and nitre with iron filings, and heating them in a test-tube. Another method of producing ammonia, through the agency of platinum sponge, is described under the head of Platinum.

How is ammonia commonly prepared?

539. PREPARATION.—Ammonia is commonly made from salts that contain it, by using some strong base to retain the acid,

and set the gas at liberty. Potash or lime may be used for this purpose. Introduce into a test-tube about half an inch of a stick of fused potash, and cover it with powdered sal-ammoniac. On the addition of water to dissolve them, ammonia will be immediately evolved. Rest the tube on the table, and place a wide-mouthed vial over it to collect the gas.

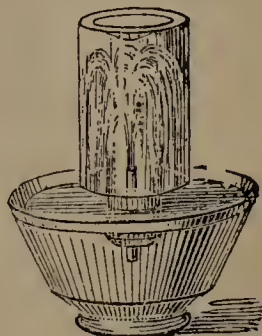


How is its solubility in water proved?

540. SOLUTION IN WATER.—AQUA AMMONIÆ. Bring the mouth of the vial filled with ammoniacal gas, quickly, into a bowl of water. The water will swallow up the gas so rapidly as to rise and fill the vial, producing a weak solution of ammonia or hartshorn. If only a small portion of water be allowed to enter, and the vial be then removed from the bowl and shaken, the hartshorn obtained will be comparatively strong. For the preparation of the solution in large quantity, the method given in the section on Chlorine is to be preferred. The vial should be previously warmed. Newly slaked lime may be substituted for potash.

How may the ammonia be employed to produce a jet of water?

541. A MINIATURE FOUNTAIN.—Fill a pint vial with ammonia, by the method above given, and immediately introduce, airtight, into its mouth, a moist paper stopper with a bit of pipe-stem run through it. Then invert the bottle into a bowl of water. The absorption by the first portions of water that enter will be so com-



plete as to produce a vacuum, into which more water will rise, in a jet, as represented in the figure.

*Explain its
action on
acids.*

542. ALKALINE PROPERTIES.—Bring the material for making ammonia into a tea-cup or similar open vessel. Hold a strip of litmus paper, previously reddened by an acid, in the gas, as it is evolved. The acid will be neutralized by the ammonia, and the paper restored to its original color. Any substance which is very soluble and neutralizes strong acids, is called an *alkali*. As ammonia has this property, and is also volatile, it is therefore called a *volatile alkali*. The same experiment with litmus paper, may be also made with the hartshorn obtained in the last experiment.

*Describe its
effect on acid
vapors.*

543. IT FUMES WITH ACID VAPORS.—Moisten a piece of paper with strong muriatic acid, and wave it to and fro through the gas. White fumes are produced, by the union of the muriatic acid and the ammonia. In uniting, they form small particles of muriate of ammonia, or sal-ammoniac, in the air. It is of these that the fumes consist. It will be observed, that in this experiment the material from which the ammonia was originally prepared is reproduced. The same fumes are formed on waving a paper moistened with muriatic acid through the atmosphere of a stable. Ammonia is constantly evolved in such places, from the decomposition of animal matter.



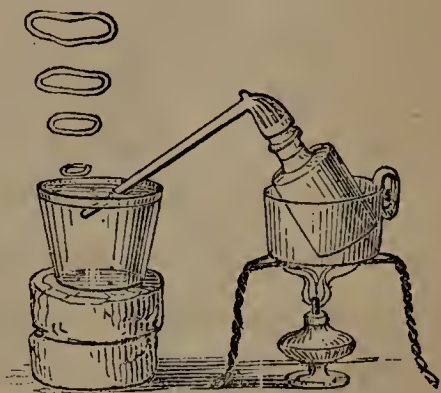
PHOSPHURETTED HYDROGEN.

What is phosphuretted hydrogen?

544. DESCRIPTION.—Phosphuretted hydrogen is a colorless gas, of an odor that has been compared to that of putrid fish. It is spontaneously inflammable by contact with the air. In the relative proportion of its elements, it corresponds with ammonia. This gas is sometimes produced in the decay of vegetable and animal matters. The *jack-o-lantern*, or *will-o-the-wisp*, sometimes seen in swamps and grave-yards, is supposed to have its origin in the spontaneous production and combustion of this gas.

How is it prepared?

545. PREPARATION.—Phosphuretted hydrogen is made from phosphorus, with the help of water and an alkali. Water furnishes the requisite hydrogen, if lime or potash is at the same time present. Introduce into a small vial two-thirds full of water, a stick of ordinary fused potash, broken in pieces, and a bit of phosphorus of the size of a pea. On the application of heat, this gas is evolved. It is carried through a pipe-stem, and allowed to bubble up through water contained in a tea-cup or bowl, as represented in the figure. If the atmosphere is still, the bubbles, as they burst and inflame, form beautiful white rings, which rise in succession into the air. These rings consist of particles of phosphoric acid, produced by the combustion of the phosphorus which



is contained in the gas. In order that the gas may be safely evolved, it is best to heat the vial in a tea-cup containing salt dissolved in three times its bulk of water. The addition of salt has the effect of raising the boiling point. The comparatively high temperature required, may thus be obtained without exposure of the vial to the direct flame of a lamp.

Explain the above process. 546. EXPLANATION.—In the action which occurs in making phosphuretted hydrogen from potash, water, and phosphorus, the latter plays the part of an extremely rapacious element. It makes no distinction in the objects of its appetite, but seizes upon both oxygen and hydrogen of the water, two substances as widely different from each other as possible. It forms with the one, phosphuretted hydrogen, and with the other, what might be called phosphuretted oxygen, but is, in fact, an acid. Potash is employed in the process, to promote the formation of this acid. In its absence, water resists the affinities of the phosphorus, and neither acid or phosphuretted hydrogen are obtained.

COMPOUNDS OF HYDROGEN WITH CARBON.

547. Most of the compounds of carbon and hydrogen belong to the vegetable world, and will therefore be more properly considered in the chapter on organic chemistry. Only two of them, which exist ready formed in nature, will be here mentioned.

LIGHT CARBURETTED HYDROGEN.

*What is light
carburetted
hydrogen?
Where does it
occur?*

548. DESCRIPTION.—Light carburetted hydrogen is a colorless, inodorous, inflammable gas, about half as heavy as air. Its molecule contains two atoms of carbon to four of hydrogen. It is produced in ponds and marshes, by the decomposition of vegetable matter under water, as will be more fully explained in Part IV. From this circumstance it is also called *marsh gas*. Mixed with other gases, it issues from fissures in coal mines, forming the *fire damp* formerly so much dreaded on account of its explosive properties. As coal is of vegetable origin, the gas of the mines which proceeds from it is also traceable to the vegetable world. In some districts, and more particularly in regions where borings are made for salt, it issues from the earth in sufficient quantity to form the fuel which is required to boil down the brine, or even to illuminate villages.

*How is it pre-
pared?*

549. PREPARATION.—An impure, light carburetted hydrogen, is obtained from wood by simple heating. For this purpose, saw-dust or bits of shavings are heated in a test-tube. The gas may be burned in a jet as fast as formed. The product thus obtained is not pure, but mixed with olefiant and other gases which make the flame more luminous. The pure gas may be made from strong vinegar, (acetic acid,) by the agency of heat and potash, as will be explained in the latter part of this work.

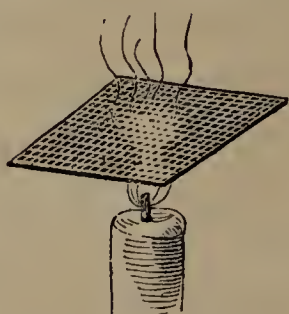


Explain the cause of explosion in mines.

550. EXPLOSIONS IN MINES.—Marsh gas forms, with air, an explosive mixture before alluded to, which is often the occasion of fearful accidents in mines. The experiment may be made with olefiant gas, which has the same explosive property. This property belongs, indeed, to most gases and vapors which contain hydrogen; as for example, to the vapors of ether, alcohol, camphene, and “burning fluid.”

Describe Davy's safety lamp.

551. DAVY'S SAFETY LAMP.—The distinguished English chemist, Davy, devised a method of security against these explosions. It consists in surrounding the miners' lamp with wire gauze, which will admit air through its interstices, but will not let out flame to ignite the explosive atmosphere of the mine. This effect may be illustrated, by holding down a piece of wire gauze upon the flame of a candle. If the gauze is fine, the flame will not pass through it. This effect is owing to the reduction of temperature which the wire occasions. The subject will be better understood by reference to the paragraphs which follow, on the nature of flame.



HEAVY CARBURETTED HYDROGEN.

What are the properties of olefiant gas?

552. DESCRIPTION.—Heavy carburetted hydrogen is a colorless gas, of peculiar sweetish odor, also known as olefiant gas.

It is nearly twice as heavy as the light carburetted hydrogen just described, and contains twice the quantity of carbon. It forms a small proportion of the *fire damp* of mines and salt borings, before described.

How is it prepared?

553. PREPARATION.—Heavy carburetted hydrogen is made from alcohol, by the decomposing action of sulphuric acid. Bring into a test-tube a tea-spoonful of alcohol, with a little sand, and add four times as much oil of vitriol. On heating over a spirit lamp, the gas is evolved, and may be burned like the gas just described, at the mouth of the tube. The acid employed has the effect of retaining part of the elements of the alcohol, and allows the rest to escape as olefiant gas. The reaction* is more fully explained under the head of organic chemistry.

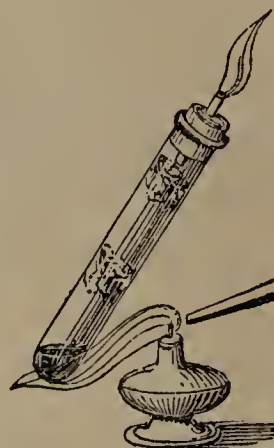
How is illuminating gas made?

554. ILLUMINATING GAS.—Gas for illumination is commonly prepared from bituminous coal. Such coal is principally composed of carbon and hydrogen. A portion of these elements pass off under the influence of a high temperature, in the form of gas. The product is rather a mixture of gases, among which light and heavy carburetted hydrogen are the principal. The process may be illustrated, by heating a little pulverized bituminous coal in a test-tube. If the heat is intense, coal tar will be produced at the same time. The illuminating power of gas is principally derived from heavy carburetted hydrogen. Its quality, within certain limits, depends on the relative proportion of this constituent.

* The term *reaction*, signifies, in chemistry, the mutual action of chemical agents.

How is it purified?

555. PURIFICATION.—The gas as it rises, contains ammonia and sulphuretted hydrogen, two impurities which it is essential to remove. The first may be stopped in its passage, by a loose wad of moistened paper; the last, by a similar wad, moistened with solution of sugar of lead. The papers having been introduced, the pipe-stem is fitted to the tube with a paper stopper, and the tube heated over the alcohol flame with the help of a blow-pipe. When the coal has become red hot, the gas will pass off in sufficient quantity to be ignited at the extremity of the tube.



How are the impurities shown?

556. At the conclusion of the process, the upper wad contained in the tube will be found blackened by the sulphuretted hydrogen which it has retained. On removing the second one, it will be found to smell of ammonia. The presence of this body may also be shown, by the fumes which it yields with muriatic acid.

Describe the process in gas works.

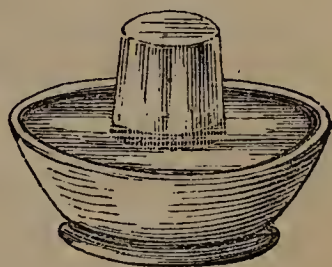
557. ARRANGEMENTS IN GAS WORKS.—The process in gas works is essentially the same, as that above described. The coal is heated in iron retorts. The tar collects in pipes leading from it. Carbonate of ammonia is washed out by a jet of water, which plays in an enlargement of the pipe. Lastly, sulphuretted hydrogen is removed by the retentive power of a metallic base, lime being generally substituted for lead.

558. COLLECTION AND DISTRIBUTION.—

How is illuminating gas collected and distributed?

After purification, the gas is collected in large iron holders called *gasometers*.

These may be represented by the inverted tumbler of the figure. Gas pouring in from below would lift and fill it. If an orifice were made in the top, the tumbler would immediately settle into the water. The air would, at the same time, escape through the orifice. The distribution of illuminating gas, from public gas works, is effected on the same principle. The weight of the sinking gasometer, is sufficient to press it through pipes, to all parts of a large city.



How may gas be made from wood?

559. GAS FROM WOOD.—Gas may be

made from wood by the same means above given. Only a moderate heat is required, in this case, to produce tar at the same time. Gas of higher illuminating power than that prepared from wood or coal may also be made from oil, fat, or rosin. Even refuse vegetable substance may be employed. A pound of dried grape skins have been found to yield 350 quarts of excellent illuminating gas. The dried flesh of animals has sometimes been used for its manufacture.

FLAME.

What is said of flame?

560. FLAME.—Nothing in nature is, to the uninstructed eye, more mysterious than flame. It is, seemingly, body without substance, and

shape, without coherence. It is created by a spark, and annihilated by a breath. Invulnerable itself, it destroys whatever it touches. Divided and subdivided, it is still the same, yet endowed with the power of resolving other materials into their elements. Chemistry resolves this mystery, and gives us the satisfaction of definite knowledge in its place. But, as in all similar cases, while satisfying the understanding, it opens new fields to the imagination. The subject of combustion, as involved in flame, introduces us, for example, to a knowledge of the grand system of circulation of matter as set forth in the last chapter of this work.

Explain the structure of flame.

561. STRUCTURE OF FLAME.—EXPLANATION.—Every lamp or candle, is a gas factory, in which gas is first produced out of oil or fat, by the fire which kindles it, and afterward by the heat of its own flame. A flame, if carefully observed, will be found to consist of three distinct parts; a dark centre, a luminous body, and a faint blue envelop. The dark centre is unburned gas. The body of the flame consists of particles of carbon or lamp-black, heated white hot by the combustion of hydrogen. In the exterior blue envelop, the carbon particles are consumed as they are crowded outwards by the flow of newly-formed gas.



What is the effect of flame on metals?

562. EFFECT OF FLAME ON METALS.—If a tarnished penny be held perpendicularly in the flame of a lamp or candle, the

portion within the flame will lose its coating of oxide, while the exterior portions at the same time become more deeply oxidized, and consequently, darker colored. It is because there is an excess of carbon and hydrogen in the interior of the flame, to take oxygen from the metal, by their superior affinity, and pass off with it as gas or vapor. In the outside, on the other hand, there is an abundant supply of air to impart oxygen or, in other words, to oxidize. By moving the coin to and fro after it is once thoroughly heated, the instantaneous conversion of metal into oxide, and oxide into metal, may be readily observed. A beautiful play of colors, like those upon a soap bubble, will be found to attend the transformation. The flame of a spirit lamp is, in some respects, preferable for this experiment.

*What is the
oxidizing
flame?*

563. OXIDIZING FLAME.—The blue envelop of the flame, which, with the hot air adjacent, has the property of oxidizing metals, is called the oxidizing flame.

*What is the
reducing
flame?*

564. REDUCING FLAME.—The body of the flame, which, with the heated gas within it, has deoxidizing effects, and reduces oxides again to the metallic form, is called the reducing flame. The process of deoxidizing is called *reduction*.

*Describe a
blow-pipe of
simple construction.*

565. THE BLOW-PIPE.—The peculiar effects of both the oxidizing and reducing flame, may be still better obtained by help of the simple mouth blow-pipe. In want of a metallic tube, a common tobacco-pipe, to the bowl

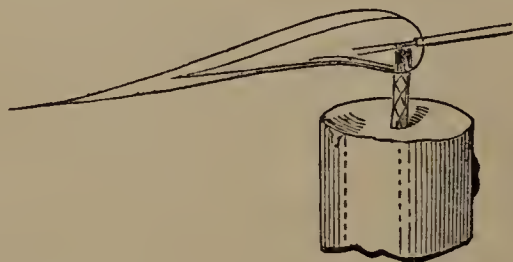
of which a piece of a second stem is fitted, as represented in the figure, may be made to answer the purpose. With its aid, a lamp or candle flame is converted into a miniature blast furnace. The mouth is applied at the end of the long stem, while the shorter one carries the blast to the flame. The orifice of the latter should be extremely small. It may be so rendered, by filling with clay and then piercing it with a needle.



*How is the
blow-pipe used
for oxidation?
Give an ex-
ample.*

566. OXIDIZING BLOW-PIPE FLAME.—To oxidize with the blow-pipe, the flame, mixed with a large proportion of oxygen, is blown forward upon the metal, or other material, subjected to experiment. This is effected by introducing the extremity of the blow-pipe, a little within the flame.

The air of the lungs becomes thus mixed with the rising gases. The result is a slender, blue flame, at the point of

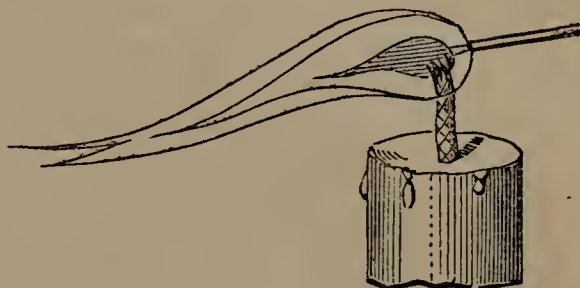


which, within its fainter blue envelop, the metal is to be held. A piece of lead, of the size of a grain of wheat, placed on charcoal, hollowed out for the purpose, and exposed to the flame, will soon be converted into litharge. The oxide will be recognized by the yellow incrustation which it forms upon the charcoal support

*How is the
blow-pipe used
for reducing
metals?*

567. REDUCING BLOW-PIPE FLAME.—To convert oxides into metals, or in other words, to *reduce* with the aid of the blow-pipe, the gases of the flames are

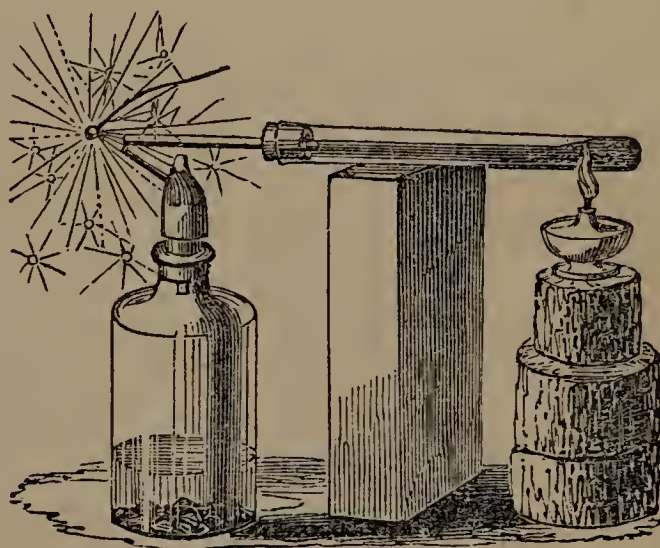
blown forward, upon the substance, mixed with little air. The extremity of the blow-pipe is placed against the outer wall of the flame, a little higher than in the previous case.



The flame thus produced is yellow, and of the shape represented in the figure. The oxide to be reduced, is to be placed within the yellow body of the flame, but near its termination. The litharge produced in the last experiment, may be re-converted, by this means, into metallic lead.

568. OXYHYDROGEN BLOW-PIPE.—The compound or *oxyhydrogen* blow-pipe, as commonly constructed, consists of two gasometers, containing, the one, oxygen,

and the other hydrogen gas. Tubes leading from these, are brought together at their extremity, and the two gases are burned in a single jet. The heat thus produced, is the most intense that has ever been realized except



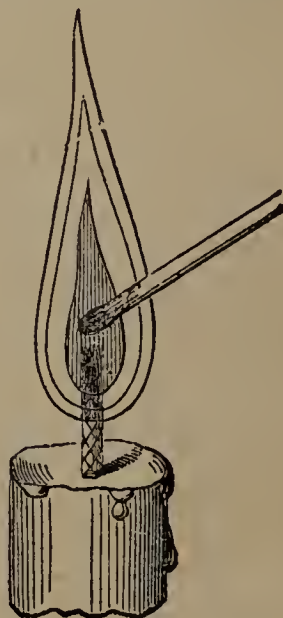
by galvanic means. Iron, copper, zinc, and other metals, melt and burn in it readily; the former, with beautiful scintillations, and the latter, with characteristic colored flames. With a sufficiently constant flame

platinum also may be readily fused. The apparatus represented in the figure, furnishes a simpler means of obtaining similar results. An abundant flow of hydrogen is required, and a pint bottle should, therefore, be employed in its preparation. To retain it free from water, which would tend to reduce the heat of the flame, a little cotton may be introduced into the bowl of the pipe through which it passes. In evolving the oxygen, only a part of the tube should be heated at a time lest the gas should be too rapidly evolved.

How is the nature of flame further illustrated?

FLAME CONTINUED.—The student will already have found abundant evidence that air or oxygen is essential to combustion.

A still more striking illustration of the subject remains to be given. A phosphorus match, if suddenly introduced into the interior of a flame, notwithstanding the high temperature in its vicinity, is not ignited. The wood burns off, but the phosphorus of the match does not undergo combustion. The same principle may be illustrated by holding a match for a moment through the body of the flame. It is consumed at the sides, while the centre remains unburned.



CHAPTER II.

METALS.

*How may the
metals be clas-
sified?*

569. CLASSIFICATION.—The metals may be arranged in groups or classes, according to their affinity for oxygen. Those which tarnish or rust most readily, come first in order, while the last group is made up of the noble metals, which retain their brilliancy unimpaired.

*Describe the
metals of
Class I.*

570. CLASS I. POTASSIUM AND SODIUM. These two metals combine with oxygen so eagerly, as to tarnish instantaneously on exposure to the air. They even seize on that which is contained in water and expel its hydrogen. The hypothetical metal ammonium, is described in connection with this group, because of the similar properties of its compounds.

*Describe Class
II.*

571. CLASS II. BARIUM, STRONTIUM, CALCIUM, MAGNESIUM.—The metals of this class show their affinity for oxygen in the same manner as those of Class I. But they are inferior, in this respect, to both potassium and sodium. Either of these metals can deprive them of the oxygen with which they may have combined.

*Describe Class
III.*

572. CLASS III. MANGANESE, ALUMINIUM, IRON, CHROMIUM, COBALT, NICKEL.—The metals of this class tarnish less rapidly than the foregoing, by exposure to the air. In order that they may decompose water, and appropriate its oxygen, they re-

quire the stimulus of an acid, or of heat. Except in the case of manganese, the heat must be sufficient to convert the water into steam. Strictly speaking, therefore, they do not decompose water, but steam.

Describe Class 573. CLASS IV. TIN AND ANTIMONY.—
IV.

Tin and antimony tarnish less readily than the metals of the previous class. To enable them to decompose water, and appropriate its oxygen, they require the stimulus of a red heat. An acid, or moderate heat will not suffice.

Describe Class 574. CLASS V. COPPER, BISMUTH, AND
V.

LEAD.—Although copper and lead become tarnished, or covered with a thin film of oxide, rather more readily than the metals of the last two groups, their affinity for oxygen under other circumstances is less. This is evident in the fact that a red heat enables them to decompose water and appropriate its oxygen but feebly. Acids will not suffice. Bismuth does not tarnish so readily as copper or lead.

Describe Class 575. CLASS VI. MERCURY, SILVER, PLA-
VI.

TINUM, AND GOLD.—The metals of this class do not tarnish, and do not decompose water under any circumstances. Even if made to combine with oxygen by other means, they yield it again very readily, and return to the condition of metals. They are called the *noble* metals.

CLASS FIRST.

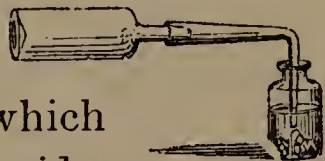
POTASSIUM.

*Potassium—
description;
solvents;
occurrence?*

576. DESCRIPTION.—Potassium is a bluish white metal, lighter than water, and soft, like bees-wax. Like wax, it is also converted by the heat of an ordinary fire into vapor. Water and acids dissolve it readily. The metals of this and the following groups, were discovered by Sir Humphrey Davy, early in the present century. They were first produced by the galvanic process. Potassium is a constituent of many rocks, of all fertile soils, and of the ashes of plants. The more important minerals which contain it, are mentioned in Chapter III.

*How is potas-
sium pre-
pared?*

577. PREPARATION.—Potassium is made from carbonate of potassa, by removing its carbonic acid and oxygen. This is accomplished by heating intensely with charcoal, which removes both in the form of carbonic oxide.



The metal which accompanies the gas, in the form of vapor, is condensed by naphtha, instead of water. The process is essentially the same as that for preparing phosphorus, but requires apparatus beyond the reach of the ordinary experimenter. *Cream of tartar*, if heated, is converted into a nearly suitable mixture of carbonate of potassa and pure carbon, for this purpose. A small quantity of charcoal, in fragments, is added, and the whole heated intensely in an iron retort.

Explain the action of potassium on water.

578. COMBUSTION ON WATER.—Potassium, if thrown upon water, is immediately ignited and burns with a beautiful violet flame. Strictly speaking, it is not potassium which burns, but the hydrogen which it sets at liberty, Owing to its strong affinity for oxygen, it takes this element from water, liberating, and at the same time kindling, the hydrogen with which it was before combined. The color of the flame is due to a small portion of vaporized potassium which burns with this gas as it is evolved. The globule of metal used in this experiment gradually disappears, because the potassa which it forms by uniting with oxygen is soluble in water.



State the uses of potassium.

579. USES OF POTASSIUM.—Potassium has not been applied to important uses in the arts, but is a valuable agent in the hands of the chemist. It is a key which unlocks many substances from the prison in which nature has confined them. Through its agency, brilliant metals may be obtained from lime, magnesia, and common clay.

On what does its action depend?

580. This effect depends on the superior affinities of potassium, which enable it to appropriate oxygen, chlorine, and other substances, with which the above and several other metals are combined in nature, and to isolate the metals themselves. The potassium is at the same time converted into oxide or chloride of potassium,

both of which are soluble in water, and may be washed away from the metal which has been produced.

SODIUM.

*Sodium—description,
preparation,
solvents, and
occurrence?*

581. PROPERTIES.—The metal sodium is similar in its properties to potassium. It is prepared by similar means, from carbonate of soda, and may be employed by the chemist, for the same purposes. It occurs, principally, in nature, in the form of common salt. Thrown upon water, it decomposes it, without however igniting the hydrogen which is evolved.* Sodium is readily soluble either in water or acids.

For what purpose is it used?

582. USES OF SODIUM.—Sodium is now prepared in large quantities, in France, as a material to be used in the manufacture of the metal *aluminium*. Its cost, a few years since, was ten dollars an ounce. It can now be produced for less than a dollar per pound.

AMMONIUM.

What is said of ammonium?

583. Ammonium is a compound of nitrogen and hydrogen, which is presumed to be a metal. Its molecule contains one atom of nitrogen, to four of hydrogen. If a metal, it differs from all others, in being a compound, and not a simple element. There are, however, good grounds

* If sodium is wrapped in paper, to prevent waste of heat, it burns with flame, like potassium, upon water.

for believing in the existence of such a compound gaseous metal. The chloride of ammonium is named in accordance with this view. Judging from the properties of the salt, we might reasonably expect, by removal of its chlorine, to obtain from it a substance with metallic properties, as well as from chloride of sodium or common salt. But the experiment does not justify the expectation. As soon as the chlorine is removed, the metal also decomposes, and a mixture of gases is the result. The principal ground for attributing a metallic character to the combination of nitrogen and hydrogen gases, in the preparations above stated, has been already indicated. They supply, in certain salts, the place which known metals fill in the other and similar compounds. A confirmatory experiment is described in the succeeding paragraphs.

State another reason for believing in the existence of a metal ammonium.

584. AMMONIUM AMALGAM.—Another ground for believing in the existence of ammonium with true metallic properties, is found in the following experiment: If chloride of ammonium is mixed with an amalgam of sodium and mercury, a double decomposition ensues. The chlorine and sodium unite to form common salt, while the mercury combines with the ammonium without losing its metallic lustre. But there is no instance of this retention of metallic properties in the combination of mercury or any other metal with any non-metallic substance. The inference is that ammonium is a metal. But any attempt to isolate it by re-



moval of the mercury from the amalgam is ineffectual. As soon as this is done the ammonium is resolved into gaseous ammonia and hydrogen. This change takes place, indeed, spontaneously.

How is the amalgam experiment performed? 585. In performing the above experiment, a small globule of potassium or sodium is heated with a thimble full of mercury in a test-tube, and a strong solution of sal ammoniac added. The mercury increases in bulk without losing its lustre, and continues to expand till it fills the tube or glass with a light pasty amalgam.

CLASS SECOND.

BARIUM—STRONTIUM—CALCIUM—MAGNESIUM.

Barium—description, production and solvents? 586. **BARIUM.**—Barium is a soft silvery metal, easily tarnished in the air. It is made from baryta, by the process already described in the section on Potassium. Its compounds, including baryta, from which it is prepared, are hereafter described. Barium is soluble in water and most acids.

Strontium—description, production and solvents? 587. **STRONTIUM.**—Strontium is very similar to barium, but darker in color. It is produced from strontia by a similar process. Its solvents are also the same.

Calcium—description, production and solvents? 588. **CALCIUM.**—The metal calcium is similar to barium, and is made from lime by the use of potassium, as before described. Its solvents are the same as those of the metals above-named.

*Magnesium—
description,
preparation,
solvents and
occurrence?*

589. **MAGNESIUM.**—Magnesium is a soft white metal, prepared from its chloride instead of the oxide, by similar means.

None of the metals of this class have as yet been applied to any useful purpose in the arts. Water oxidizes magnesium as it does the other metals of the class, but converts it into an insoluble white powder. Most acids dissolve it.

CLASS THIRD.

ALUMINIUM

*Aluminium—
description oc-
currence, and
solvents?*

590. **DESCRIPTION.**—Aluminium is a bluish white metal made from common clay. It is about one-third as heavy as iron. It fuses at the same temperature as silver, and preserves an untarnished surface in the air. It does not decompose water, even with the aid of boiling heat. Alloyed with iron, it protects the latter from the action of the air. This metal is a constituent of common clay, and therefore a part of all fertile soils and the rocks that produce them. It is also a constituent of numerous minerals. By its discovery every clay bank is converted into a mine of valuable metal.

*How is it pre-
pared?*

591. **PREPARATION.**—Aluminium is prepared like magnesium, from its chloride, by fusion with potassium or sodium. The latter metal is commonly employed. The fluoride may also be used in the process, or the mineral *cryolite*, which

is a compound of fluoride of aluminium with fluoride of potassium. The latter constituent interferes in no wise with the process. The method of preparing the chloride, as a material for the production of the metal, is given in the section on Chlorides.

What is the action of acids on it? 592. ACTION OF ACIDS.—Muriatic acid is its proper solvent, and forms with it a colorless solution. Nitric acid whitens it, if previously dipped into strong potash or soda. Dilute sulphuric acid is without action. Aluminium may be poured from one vessel to another in a fused condition without oxidation. Like silver it may be deposited by the galvanic process.

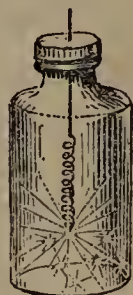
Mention its other properties. 593. It is highly sonorous, and therefore adapted to manufacture of bells. This metal is now prepared in France at about ten dollars per pound. The French government propose to use it for helmets and cuirasses, for which it is especially fitted by its lightness and tenacity.

Manganese—description, production, occurrence, solvents and uses? 594. MANGANESE.—Manganese is a grey brittle metal, produced from its oxide by heating with charcoal. It is found in nature as black oxide of manganese and as a constituent of many other minerals. It enters also in small proportions into the composition of soils. Diluted sulphuric or muriatic acid are its proper solvents, forming with it pale rose-colored solutions. The black oxide serves as a source of oxygen, and is also employed in the preparation of chlorine gas. It is also used in the production of artificial amethysts, and also to impart to glass the same violet tint.

IRON.

*Mention some
properties of
iron.*

595. DESCRIPTION.—Pure iron is nearly white, quite soft, exceedingly malleable and highly tenacious. It may be rolled into leaves so thin that a bound book containing forty-four such leaves shall be only one-fifteenth part of an inch in thickness. In the condition of perfect purity it is never seen except in the chemist's laboratory. Even the purest iron of commerce contains traces of other substances. Dilute sulphuric or muriatic acids are its proper solvents, forming with it green solutions. The addition of nitric acid or chlorine changes the color to red. Iron may be readily burned, as has already been shown in the section on Oxygen.

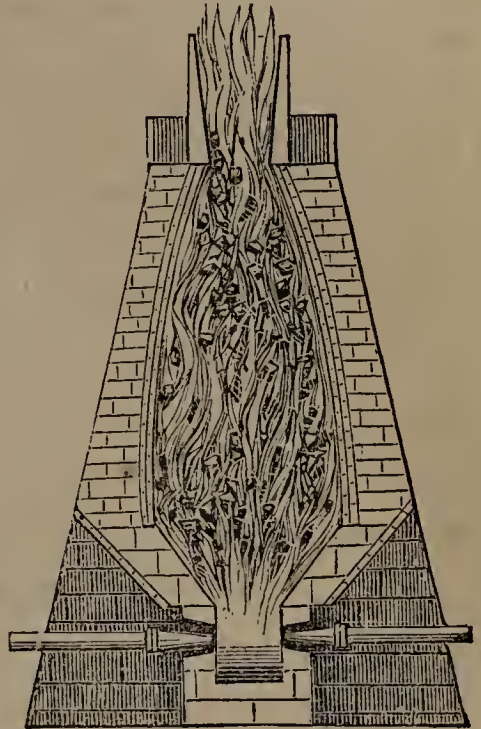


*Does metallic
iron occur in
nature?*

596. OCCURRENCE.—Iron is a most abundant metal, but is rarely or never found in the metallic form, excepting as meteoric iron. In this condition it is always alloyed with nickel. The latter metal being uniformly combined with it in masses known to have fallen to the earth as *meteors*, its presence in similar masses discovered on the surface of the earth, is regarded as evidence of their meteoric origin. Iron is a constituent of a great variety of minerals, of all soils and plants, and even of the blood of animals. The peroxide of iron, the magnetic oxide, and *clay iron stone*, are its principal ores. Whole mountains of the magnetic oxide exist in Missouri and in Sweden.

*How is iron
produced?*

597. PRODUCTION.—Iron is produced from its ores, which are impure oxides, by heating with lime, to remove the impurity; and at the same time with coal, and the gases proceeding from it, to remove the oxygen. A smelting furnace, such as is represented in the figure, being previously heated, is charged with the material in layers, and the heat maintained by the coal of the mixture. In the upper part of the furnace the materials are thoroughly dried. As they gradually settle, they become more thoroughly heated, and meet carbonic oxide from the coal below, which robs the iron of its oxygen, and converts it into particles of metal. Still lower down, the lime combines with the earthy portions of the ore, forming a liquid glass. The reduced iron thus liberated, collects, fuses, and sinks to the bottom of the furnace. From this point it is run off into channels of sand, where it hardens into *pig iron*.



*How is the
slag formed?
For what uses
may it be em-
ployed?*

598. EXPLANATION.—The ordinary impurities of the ore are clay and quartz or silica. Lime has the property of forming, with both of these, a fusible glass or slag, which floats upon the melted iron. This material is

of a light green color. But it may be otherwise colored to suit the taste, and cast into slabs, columns, architectural and parlor ornaments of great beauty. The process by which its brittleness is removed, and the slag adapted to the above uses, has not been made public.

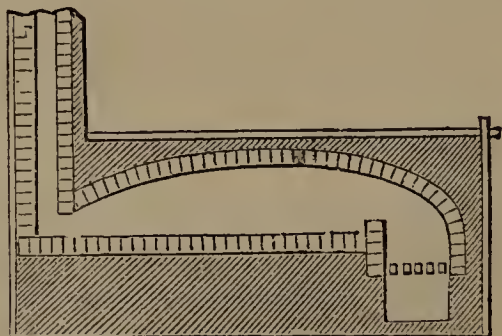
Give the composition and properties of cast iron.

599. **CAST IRON**—The pig or cast iron, as it is called, which is thus obtained from the furnace, is not pure iron, but a compound of iron with carbon. It has obtained four or five per cent. of this element from the coal with which it was reduced. The addition of carbon to its composition causes iron to melt more readily. But for its absorption, the metal would not have become sufficiently soft to flow from the furnace. Carbon has also the opposite property of making iron harder and more brittle when cold. Castings of agricultural implements and other objects, are made by remelting the pig iron, and pouring it into moulds of the required shape.

How is wrought iron made?

600. **WROUGHT IRON**.—Wrought iron is made from cast iron, by burning out its carbon. This is done in what is called a

reverberatory furnace, such as is represented in the figure. The carbon is burned out by the surplus air of the flame, which is made to play upon the molten iron. From the constant stirring which is essential, such a furnace for refining iron is called a *puddling furnace*. The



metal becomes stiffer as it loses carbon, and is then hammered and rolled into bars.

Mention an important property of wrought iron. How is iron wire made?

601. IRON WIRE.—The bar or wrought iron thus produced, is highly malleable and ductile, and may be rolled into sheets, or drawn into the finest wire. Wire is made by drawing a wrought iron bar, by machinery, through a hole of less than its own diameter, and repeating the process until the required degree of fineness is attained. Wrought iron loses its tenacity, and becomes granular and brittle, like cast iron, by long jarring. This effect sometimes occurs in the wheels and axles of railway carriages, and is the occasion of serious accidents.

How is wrought iron welded?

602. WELDING.—Wrought iron becomes soft at a certain heat, without melting. This property, which adds greatly to its usefulness, belongs to no other metal excepting platinum. In the soft state, two pieces may be united by hammering. This process is called *welding*. The surfaces to be welded are sprinkled with borax, to protect them from the air, which would form a crust of oxide of iron and prevent a perfect contact. Its further action is explained in the chapter on Salts. Beside borax, other materials having a similar effect are frequently employed.

How is steel made?

603. STEEL.—Steel may be made from cast iron by burning out half its carbon. Or it may be made from wrought iron, by returning half of the carbon which was removed in its preparation. The latter is the process generally pur-

sued. It consists in burying the wrought metal in iron boxes containing charcoal, and heating it for several days, till combination with a certain portion of the carbon is effected.

How is steel made soft or hard? 604. ANNEALING.—The hardness of steel depends upon the rate at which it is cooled. By heating it to redness, and cooling it slowly, it is rendered as soft and malleable as wrought iron. This process is called *annealing*. By cooling it very suddenly, it becomes as hard and brittle as cast iron. Steel instruments are commonly hammered out of the soft steel, and subsequently hardened.

How is steel tempered? 605. TEMPERING STEEL.—Steel hardened as above described is too hard and brittle for most uses. Any portion of its original softness and tenacity may be returned to it, by reheating and slow cooling. To restore the whole, a red heat would be required. To give back part, and make a steel so tough as not to break readily, yet sufficiently hard for cutting, a lower temperature is employed. This process is called *tempering*. The sort of temper imparted depends upon the degree of heat which has been employed.

How is the proper heat ascertained? 606. The proper temperature is ascertained by the color which the steel assumes when heated. Tools for cutting metal are heated till they become a pale yellow ; planes and knives, to a darker yellow ; chisels and hatchets, to a purplish yellow ; springs, till they become purple, or blue. In each case they are afterward slowly cooled. These colors are owing to a film of oxide of iron, which is

formed upon the steel under the influence of heat. The tint is different, according to the thickness of the film. All these colors may be seen by heating a knitting-needle in the flame of a spirit lamp. Where it is hottest it becomes blue, and this color shades off into pale yellow on either side, like the colors of the solar spectrum.

CHROMIUM.

*Chromium—
description,
production,
ores, solvents,
and uses?*

607. DESCRIPTION.—Chromium is a grey metal, not readily tarnished and so hard as to scratch glass. It is of no use in the arts in the metallic form. It is found in combination with iron, as *chromic iron*, and also in beautiful crystals, as red chromate of lead. It may be prepared from its oxide, like iron, by heating with charcoal. Its compounds are much used as paints. Chrome green and chrome yellow are among the number. Its proper solvents are the same as those of iron. The solutions of this metal are green.

COBALT

*Cobalt—de-
scription, pro-
duction, oc-
currence, sol-
vents, and
uses?*

608. DESCRIPTION.—Cobalt is another grey metal, tarnishing but slightly in the air. It is somewhat malleable. It is found combined with arsenic, as *arsenical cobalt*, and in some other minerals. As metal, it is without useful application in the arts. It may be produced like iron, by heating with charcoal,

but is more readily reduced by hydrogen. A current of this gas being made to pass through a hot tube containing the oxide, it combines with oxygen, and passes off with it as water, leaving the metal in the form of a fine powder. Its proper solvents are the same as those of iron and chromium. The solutions of cobalt are pink. The oxide is employed for imparting a blue color to glass.

NICKEL.

*Nickel—
description,
production,
ores, solvents,
and uses?*

609. Nickel is still another grey metal, lighter in color and more malleable than cobalt, and not much affected by the air. It is found in combination with copper; in the mineral called *copper nickel*. It may be prepared by either of the methods used for cobalt. Its proper solvents are the same as those of the last four metals. The solutions of this metal are green. Nickel is principally used in the preparation of the alloy called German silver. This imitation of silver is brass rendered white by the proportion of nickel which it contains. The alloy is composed of one hundred parts of copper, sixty of zinc, and forty of nickel.

ZINC.

*Zinc—de-
scription,
ores, and sol-
vents?*

610. DESCRIPTION.—Zinc is a bluish-white metal readily tarnished in the air. It is brittle at ordinary temperatures, and converted into vapor at a red heat. If

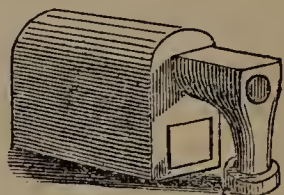
heated somewhat above the temperature of boiling water, it can be rolled into sheets. At a higher temperature it again becomes brittle. Sulphuric and muriatic acids dissolve it readily, forming colorless solutions. It is not found native. The *red oxide*, and the carbonate, called *calamine*, are among its more important ores.

*How is zinc
produced?*

*Why is a clay
retort used?*

611. PRODUCTION.—Zinc is produced from its oxide by heating with charcoal to remove the oxygen, or, in other words, to reduce it. When made from the carbonate,

the ore is previously roasted, to expel its carbonic acid and bring it to the state of oxide. As the metal is volatile at the heat required in its reduction, an



ordinary furnace, such as is used for making iron, cannot be employed in the process: the metal would be lost in vapor. A clay retort or muffle, such as is represented in the figure, is used instead. The zinc vapor condenses in the cool neck, and falls in drops of melted metal into a vessel of water placed to receive it. The carbonic oxide produced in the process at the same time, escapes into the air. It will be observed, that the process is essentially the same as that for producing potassium and phosphorus, as before described. Acids dissolve zinc, forming colorless solutions.

*How may zinc
be burned?*

How melted?

612. ACTION OF HEAT AND AIR.—Zinc may be burned by heating it on charcoal in the blow-pipe flame. It melts, and con-

verts itself rapidly in the process into white oxide of zinc. If an intense heat is employed, the vapors of the metal burst through the crust and burn



to oxide, with a brilliant greenish flame. When zinc is burned in considerable quantity in a highly heated crucible, the oxide forms flakes in the air, to which the name of *lana philosophica*, or philosopher's wool, was given by the alchemists. The metal may be melted over a spirit lamp, in an iron spoon. Oxide of zinc forms with oil a beautiful white paint, which is in some respects superior to white lead.

*Mention the
uses of zinc.*

613. USES OF ZINC.—Zinc is principally employed in the form of sheet zinc, for roofing and similar purposes. It is also used, like tin, as a coating to protect iron chains and other objects from rust. The coating is effected by plunging the iron into molten zinc, which forms an alloy upon its surface. The iron thus coated is sometimes called *galvanized* iron, though without reason, as is evident from the above process. Solutions of zinc are sometimes used to prevent the decay of wood, and to render it less combustible. It has also been employed with success, as a substitute for copper, in sheathing vessels.

CLASS FOURTH.

TIN.

*Describe the
metal Tin.
From what
ore is it made?*

614. DESCRIPTION.—Tin is a brilliant white metal, very soft and malleable, and not easily tarnished. When a bar of tin is bent, it gives a peculiar grating sound, fancifully called *the cry of tin*. This is a consequence of the friction of the minute crystals of tin of which it is composed. Its only ore is an oxide, called *tin*

stone, of which Cornwall, England, and the Island of Banca, E. I., are the principal localities.

*How is tin
produced?*

615. PRODUCTION.—Tin is produced, like iron and most other metals, by heating its oxide with carbon. The materials are heated in a small blast furnace. The carbonic oxide produced in the fire, as before explained, is the reducing agent. It takes the oxygen from the ore, and passes off with it as carbonic acid, while the metal fuses and runs to the bottom of the furnace. By heating tin before the blow-pipe, it is rapidly converted into white oxide.

*How do acids
act on tin?*

616. ACTION OF ACIDS.—Tin resists weak acids remarkably. Dilute muriatic and sulphuric acids, which dissolve most of the metals before described, act upon it but feebly. The concentrated acids dissolve it with comparative ease. Its solution, although less poisonous than those of lead, are still injurious to health. Acid food should, therefore, never be allowed to stand for a long time in tin vessels. The solutions of tin are colorless.

*What is the
action of ni-
tric acid?*

617. Nitric acid acts upon tin with energy; but, like a ferocious animal that destroys without devouring its prey, leaves it undissolved. It converts it into a white insoluble powder of oxide of tin, with the evolution of the usual red fumes. This case is an exception to the usual action of nitric acid. One portion of the acid commonly acts to produce oxide, while another portion dissolves the oxide formed. The experiment for the solution



of tin may be made with tin-foil, in a tea-cup or test-tube.

618. *Aqua-regia*, it will be remembered, *What is the action of aqua-regia on tin?* is a mixture of nitric and muriatic acids. In most cases they act, as before described, in concert, to dissolve metals that neither can dissolve alone. They act thus, also, upon tin, in small portions. But if larger quantities are employed, the mixture grows warm, and the nitric acid, as if stimulated beyond restraint, attacks the metal for itself, and converts it, as when it acts alone, into a white powder.

619. COATING PINS.—Common brass pins *How are pins coated with tin?* are coated, by boiling with cream of tartar and tin-foil or bits of tin. The acid of the *tartar* acts as solvent. Tin is then deposited on the more electro-positive brass, as in cases of galvanic decomposition. At every point where brass, tin, and the liquid are in contact, a small galvanic battery is in fact produced.

620. TIN WARE.—Tin is cast in various forms, for culinary and chemical utensils. A little lead is added to give it greater toughness. Common tin ware is made of sheet-iron coated with tin. The coating of the metal is effected by dipping well cleaned sheet-iron into molten tin. *How is tin plate made?*

621. CRYSTALLINE TIN.—Tin has a great tendency to assume a crystalline form. *How may the crystalline structure of tin be seen?* The structure may be observed on washing the surface of ordinary tin plate with *aqua-regia*, to remove the thin coating of oxide. It may be still better seen if a tin plate is heated over a

lamp till the coating melts, then suddenly cooled and afterward cleaned as above directed. The whole surface is then found to be covered with beautiful crystalline forms.

ANTIMONY.

Describe the metal antimony. From what ore is it obtained?

622. DESCRIPTION.—Antimony is a bluish white and highly crystalline metal which does not tarnish in the air. It is so brittle that it may be readily reduced to powder. The ore from which the metal is produced is the grey sulphuret, or *antimony glance*.

How is antimony produced?

623. PRODUCTION.—Antimony may be obtained from its oxide by the usual process of reduction. The sulphuret is first partially converted into oxide by roasting, and still further by carbonate of soda, which is added in the subsequent process. It is then mixed with charcoal, and intensely heated in crucibles. At a white heat the metal fuses and sinks to the bottom. The soda added in the process exchanges its oxygen for the remaining sulphur of the ore.

How may antimony be burned?

624. ACTION OF HEAT AND AIR.—If heated before the blow-pipe, antimony soon melts, and burns with a white flame. It is at the same time converted into oxide. A portion of the oxide escapes into the air, while the rest forms a white coating upon the charcoal support. At the high temperature which is here produced, the affinity of the



metal for oxygen is so stimulated, that the molten globule will continue to burn, even if removed from the flame. By directing a stream of air upon it from a pipe-stem, the combustion may be maintained till the globule is entirely consumed.

Describe an experiment with the molten globule?

625. If the molten globule is allowed to fall upon the floor, it immediately divides into hundreds of smaller globules which

radiate in all directions, leaving each a distinct track of white oxide behind it.



What is the action of chlorine on antimony?

626. ACTION OF CHLORINE.—A shower of fire may be produced by sprinkling fine powder of antimony into a vial containing chlorine gas. The metal is hereby converted into a white smoke of chloride of antimony. In its relations to the principal acids, antimony resembles tin. Its solutions are colorless.

What are the principal uses of antimony?

627. USES OF ANTIMONY.—The principal use of antimony is in the preparation of alloys, to be hereafter described. Among these, type metal is the most important. Many of the compounds of antimony, like other poisonous substances, are used with advantage in medicine. Tartar emetic is one of these medicinal compounds containing antimony.

CLASS FIFTH.

BISMUTH.

Bismuth—description, solvents, and occurrence in nature?

628. DESCRIPTION.—Bismuth is a brittle, crystalline metal of a reddish white color. It is used in making certain alloys. Like antimony it can be readily ground to powder. Crystals of bismuth may be obtained by the method described in the section on Sulphur, as represented in the figure. Nitric acid is its proper solvent and forms with it a colorless solution. Bismuth is found native, forming threads of metal in quartz rock. Its most productive localities are in Saxony.



How is bismuth produced?

629. PRODUCTION.—The metal is procured from the rock which contains it, by simple heating in inclined tubes. At a comparatively moderate temperature the bismuth fuses and runs down into vessels placed to receive it.

What is its action before the blow-pipe?

630. EFFECT OF HEAT AND AIR.—The same experiments before the blow-pipe, and with molten globules, which were described in the case of antimony, may be made with bismuth. The only difference is, that the metal does not burn with flame, and that the coating of oxide on the charcoal is yellow, instead of white.



What are the uses of bismuth?

631. USES OF BISMUTH.—Its principal use is in the preparation of alloys, to be described hereafter. One of them has the

property of fusing in water much below boiling. Several compounds of bismuth are used in medicine; the sub-nitrate, is also employed as a cosmetic. This use of it is quite hazardous, as certain gases which are often present in the air, have the effect, as will be hereafter seen, of changing its color to a deep brown or black.

COPPER.

*Copper—description,
ores, solvents?*

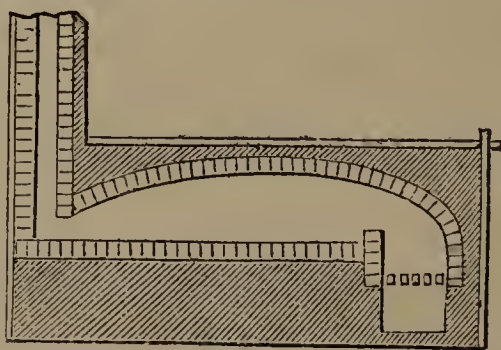
632. DESCRIPTION.—Copper is a red, malleable, and highly tenacious metal. It tarnishes in the air, but is less injured by rust than iron, and therefore more durable. Nitric acid is its proper solvent, and forms with it a green solution. Copper is found in abundance, in the metallic condition, on the southern shore of Lake Superior. It is chiseled out, in masses, from the rocks which contain it. The metal is more commonly obtained from a mineral called *copper pyrites*, which is a double sulphuret of iron and copper. It is also found as pure sulphuret, red oxide, and carbonate. Minute traces of copper are found in human blood.

*State briefly
the mode of
production.*

633. PRODUCTION.—Copper is prepared from the impure sulphuret, by

first burning out the sulphur in the air; and secondly, heating with charcoal to remove the oxygen which has taken its place. Sand

is at the same time added, to form a floating slag with the oxide of iron, and thus remove it from the molten copper.



The oxide of iron thus removed, is derived from the sulphuret of iron which is a usual constituent of copper ores.

State further particulars of the process. 634. Both of the above processes of roasting and heating with charcoal and sand, must be several times repeated before pure metallic copper is obtained. It is to be remarked that the formation of a slag which shall remove this iron, depends on the fact that its oxide is by no means so easily reduced as copper. Being once brought into the state of oxide, it remains in this condition and unites with the silicic acid of the sand.

What is the effect of heat and air? 635. ACTION OF HEAT AND AIR.—At a high temperature, copper is readily oxidized in the air. Its oxidation may be observed by holding a copper coin in the flame of a spirit lamp, as described in the section on Flame. The iridescent hues observed in the experiment, are owing to the varying depth of oxide on different portions of the coin. By long continuation of the process, the whole surface is converted into black oxide. If it is sooner suspended, and the coin plunged into cold water, a coating of red oxide containing less oxygen is obtained.

Mention some of the uses of copper. 636. USES OF COPPER.—Copper is used for a variety of purposes for which iron would be less suitable on account of its rapid oxidation. Its employment in sheathing ships, is an example. It is also a constituent of various alloys, to be hereafter described. Among these, all gold and silver coins, and the metal of gold and silver plate are included.

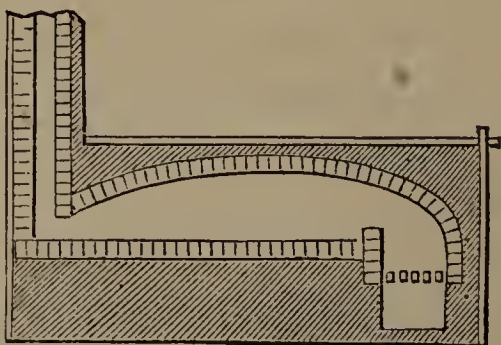
LEAD.

*Lead—de-
scription, ores
and solvents?*

637. DESCRIPTION.—Lead is a bluish grey metal, extremely malleable, and readily tarnished in the air. It is heavier than any other of the metals mentioned in this work except mercury, gold, and platinum. Nitric acid is its proper solvent, forming with it a colorless solution. The principal ore of this metal is *galena* or sulphuret of lead. Lead is also found as carbonate, sulphate, and phosphate of lead.

*How is lead
obtained?*

638. PRODUCTION.—Lead is obtained from the sulphuret by heating it with iron, to remove the sulphur. A mixture of metallic lead and sulphuret of iron are thus produced, from which the lead separates by its greater specific gravity. If the oxide of lead could be readily obtained, the reduction by charcoal would be as applicable here as in the case of other metals.



*Explain on-
other method.*

639. A SECOND METHOD.—Another method, is to heat the sulphuret and sulphate of lead together. The sulphate has a large supply of oxygen, while the sulphuret is destitute of this element. The two may be mixed in such proportions that they will together contain just enough oxygen to carry off all the sulphur as sulphurous acid. This result having been accomplished by heat, the pure metal of both remains behind. As a preparation for

this process, a portion of sulphuret is converted into sulphate by heating in a reverbaratory furnace. Both parts of the process are in practice united ; a moderate heat with abundant air being first supplied, a portion of sulphate is produced. This is afterwards more highly heated, with the undecomposed sulphuret which remains.

What occurs when lead is heated before the blow-pipe ? 640. ACTION OF AIR AND HEAT.—If lead is heated before the blow-pipe in the oxidizing flame, it melts and disappears. The charcoal support becomes at the same time covered with yellow oxide of lead or litharge. The grey coating which at first forms upon the lead, is an oxide containing less oxygen. If, on the other hand, litharge is heated in the reducing flame, it is converted into metal.



What is the action of water on lead. 641. ACTION OF WATER.—Water, with the help of the air which it always contains, acts sensibly upon lead and becomes in consequence poisonous. This action of water is most decided when it contains no foreign matter. On being conducted through leaden pipes, it becomes therefore more impure, as a consequence of its very purity.

What prevents this action ? 642. The presence of sulphates and certain other salts, such as are usually contained in spring water, prevents this effect. Those substances whose presence in water we are accustomed to regret as impurities, thus become our most efficient protectors against the poisonous effects of lead.

*Do impurities
always pro-
tect?*

643. But this rule is not without exception. Certain substances seem to increase the action. It is therefore always prudent where it is proposed to conduct water through leaden pipes, to ascertain by direct experiment, whether the particular water in question acts upon the lead or not.

*Describe the
experiment
with lead and
distilled water.*

644. ILLUSTRATION.—The difference in the action of pure water upon lead, and that which contains foreign substances in solution, may be readily proved by experiment. For this purpose, bright slips of lead may be placed in two tumblers, the one containing rain water, and the other well or spring water. The former will soon become turbid while the latter remains unaffected.

*How may the
presence of
lead be better
shown?*

645. The presence of lead in the former case may be still more strikingly shown, by adding to the water a few drops of a solution of hydrosulphuric acid. The formation of a dark cloud will show the presence of lead and indicate the danger to be apprehended.

*Describe the
lead tree and
the reason of
its production.*

646. LEAD TREE.—Dissolve some crystals of sugar of lead in thirty or forty times their bulk of water, and fill a vial with the solution. A strip of zinc hung in the vial will branch out in a beautiful arborescence of metallic lead. It may be necessary to clarify the solution by the addition of a little clear vinegar or acetic acid. A day or two will be required for the completion of the experiment. The effect depends on the



superior affinities of zinc for acetic acid. The zinc takes away acid and oxygen from successive portions of the sugar of lead, and leaves the particles of lead subject to the laws of crystallization. At the same time, the zinc having acquired possession of the acid and oxygen comes into solution as acetate of zinc. A similar arborescence is produced in a solution of silver by metallic mercury.

How are shot made? 647. MANUFACTURE OF SHOT.—Shot are prepared by pouring melted lead through perforated iron vessels. The drops are made to fall from a great height, that they may become cooled and solidified in their descent. They are caught in water that their shape may not be impaired. Having been assorted by means of sieves, they are polished in revolving casks containing a small portion of black lead or plumbago.

Mention other uses of lead. 648. OTHER USES OF LEAD.—In the form of sheet lead this metal is applied to a variety of familiar uses. It is also largely employed in the manufacture of lead tubing. It is a constituent of various alloys, among which pewter and type metal are the more important.

CLASS SIXTH.

MERCURY.

Mercury—description, solvents, ores, discovery? 649. DESCRIPTION.—Mercury is a white fluid metal of high lustre and beauty. It retains the fluid condition at all ordinary temperatures, and is only rendered solid by

extreme cold. Nitric acid is its proper solvent. Mercury is sometimes found in the metallic form, but more commonly as the sulphuret or *cinnabar*, which is its principal ore. It is said that the mines in Peru were accidentally discovered by a native hunting among the mountains. Laying hold of a shrub to assist him in his ascent, he tore it up by the roots, and a stream of what he supposed to be liquid silver flowed from the broken ground.

How is mercury obtained? 650. PRODUCTION.—Mercury is prepared from the sulphuret, by simple roasting in a current of heated air. This metal yields its sulphur so readily to the oxygen of the air that no other agent is essential in its production. The mercurial vapors pass along with the gas, into tubes or chambers where the temperature is lower, and are there condensed to the liquid form.

Mention other methods. 651. Mercury may also be produced from the sulphuret by the employment of iron filings to remove the sulphur, as in the case of lead. Burned lime may also be used. Its calcium combines with the sulphur and uses its own oxygen for the partial conversion of the sulphuret thus formed into sulphate of lime.

What is the action of heat and air on mercury? 652. ACTION OF HEAT AND AIR.—Mercury, like water, may be boiled away and converted into vapor by the application of heat. At 39° below zero it freezes. It is always to be borne in mind in experiments with this metal and its compounds, that its fumes as well as its salts are extremely poisonous. By free access of air and

moderate heat, mercury may be gradually converted into red oxide, but a higher temperature expels the oxygen thus absorbed, and the oxide is again converted into metal. This production of a metal from an oxide, by heat alone, is characteristic of the noble metals. They are loth to obscure their splendor in rust ; if it is forced upon them, they need but little assistance of heat to throw it off and re-assume their original beauty.

653. AMALGAMS—GLASS MIRRORS.—

*What are
amalgams?
How are mir-
rors silvered?*

Mercury combines with many metals forming compounds which are called *amalgams*.

When the mercury is in large proportion they are fluid. Gold, silver, and lead, for example, may be dissolved in mercury. This solvent power of mercury is usefully applied in extracting gold from the rocks which contain it. The beautiful silvering of mirrors consist of an alloy of tin and mercury. Tin foil is applied to the glass, and being afterward drenched with mercury, the excess is removed by pressure. The tin has thus absorbed about one-fourth of its own weight of mercury.

*How may a
copper coin be
similarly sil-
vered?*

654. A copper coin may be similarly silvered by rubbing with metallic mercury, or keeping it well moistened for some time with a solution of mercury in nitric

acid. If the solution is quite acid, it must first be nearly neutralized by ammonia. The coin is to be afterward polished. The chemical action which takes place in this case is similar to that explained in the case of the *lead tree*. By drawing a line across a thin brass plate with a pen dipped in solution of mercury,

the plate will be so weakened that it may afterward be readily broken.

655. OTHER USES OF MERCURY.—The compounds of mercury are extensively used in medicine. *Corrosive sublimate*, a poisonous chloride of mercury, is employed for the destruction of vermin. It is also used in what is called the *kyanizing* process, to impregnate wood and other vegetable and animal substance, and thus prevent their decay. Another important use of mercury is found in the manufacture of barometers and thermometers. It is especially adapted to the measurement of heat, by its fluidity at low temperatures and its ready and equable expansion.

Mention some other uses of mercury.

SILVER.

656. DESCRIPTION.—Silver is a lustrous white metal of perfect ductility and malleability. Its loss of lustre on exposure, is owing to the presence of a small proportion of sulphuretted hydrogen in the air. Nitric acid is its proper solvent, though for certain purposes oil of vitriol is preferred. Silver is often found native, but more frequently combined with sulphur as *silver glance*. Galena or sulphuret of lead always contains it in small proportion, and sometimes to the amount of one or two per cent.

Silver—description, ores and solvents?

How is silver obtained?

657. PRODUCTION.—Silver is prepared from the sulphuret, by first roasting the ore

with common salt, in order to convert it into chloride. Iron is subsequently employed to remove the chlorine and isolate the metallic silver.

Give the complete process. 658. Mercury is added with the iron, in order that it may dissolve the silver from the mass of roasted ore and iron as fast as it is formed. The materials are agitated with water for many hours together. At the end of the process the mercury, with its load of silver, is drawn off from the bottom of the cask. The solution of silver in mercury is afterward filtered through buckskin or closely woven cloth, which allows a large part of the liquid metal to pass, while the silver with a small portion of mercury is detained. The silver is then freed of its remaining mercury by heat. The above process is called *amalgamation*.

Describe the process for obtaining silver from lead.

659. SILVER OBTAINED FROM LEAD.—Almost all lead, as produced from galena and its other ores, contains a certain proportion of silver. The latter metal may be freed from a large part of the lead by melting the alloy and then allowing it to cool slowly. Most of the lead solidifies in small crystals, and may be skimmed out with an iron cullender. An alloy containing silver in large proportion remains in the liquid condition. It is afterwards solidified by further cooling. The above is called Pattinson's process.

How is the remaining lead separated?

660. CUPELLATION.—The remainder of lead is separated from the silver by converting it into oxide, in a current of heated air. The silver does not oxidize under these circumstances, but retains the metallic form.

The mass of metal grows smaller as the process proceeds, till finally pure silver remains. The moment of its production is indicated by a beautiful play of colors and a sudden brightening of the metal. The above process is carried on upon a hollowed and compacted mass of bone-ash called a *cupel*. The object of the cupel is not alone to support the metal, but to absorb the hot and fused oxide of lead as fast as it is formed. If a little copper is present, it is also absorbed with the lead. The process is called *cupellation*.

How may the process be illustrated?

661. It may be illustrated on a small scale, by making an excavation in a piece of charcoal, and pressing into it a lining

of well burned and moistened bone ash. A globule of lead, to which a little silver has been added, is to be heated on the support in the oxidizing flame.



For separating a small quantity of lead from silver, the bone ash is not essential. The process may be conducted before the blowpipe, upon the naked charcoal. A small portion of silver may often be obtained from the lead of commerce by this means.

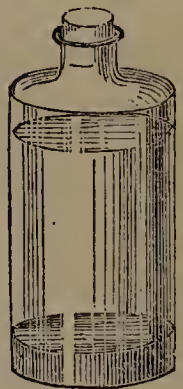
What is said of silver coins?

662. SILVER COIN.—The standard silver of the United States is an alloy containing ten per cent. of copper. Silver plate should have the same composition. The object of alloying with copper, is to impart greater hardness to the metal, and secure against the gradual loss from attrition which would otherwise occur. Spanish silver often contains a small proportion of gold. The gold is left as a black

powder, in dissolving such coins in nitric acid. Its color and lustre may be brought out by rubbing.

What is assaying, and why necessary? 663. THE SILVER ASSAY.—*Assaying* is the process by which the proportion of metals in an alloy is ascertained. In all establishments where money is coined, assaying is an important part of the work of the establishment. The precious metals, as received at the mint, commonly contain a certain proportion of other metals. But it may be too much or too little. It is the business of the assayer to ascertain its precise composition, that the metal may be rendered purer, if necessary, or be further alloyed if found purer than the standard.

Describe the process of assaying. 664. As a preparation for the silver assay, a sample, containing an ounce, or other definite weight of the impure metal, is dissolved in nitric acid. The dissolved silver has the property of becoming solid again, and sinking to the bottom of the clear solution as a white curd, just in proportion as common salt is furnished to it. But the other metals which may be present as impurities have no such effect. It follows, that the amount of silver present, is just in proportion to the amount of salt it is necessary to supply before the precipitation or formation of the curd ceases. Now, the assayer knows beforehand, how much salt he must supply to the solution of an ounce of metal if it be all silver. If he finds that an ounce of the sample, requires to be supplied with the same quantity before the precipitation ceases, he knows that the metal is all silver ;



if but half as much is required, he knows that it is but half silver. Having ascertained the true proportion, the assay is completed. The salt required in the process is employed in the form of a solution, and the quantity used is known by pouring it from a graduated vessel.

Explain the chemical action in the above process.

665. EXPLANATION.—The curd which forms in the above process is insoluble chloride of silver, formed from the silver of the solution and the chlorine of the salt.

The nitric acid and oxygen, which were combined with the silver, at the same time unite with the sodium forming nitrate of soda which remains in solution.

Describe the method of extracting silver from copper.

666. SILVER SEPARATED FROM COPPER.

Copper obtained from certain ores contains so much silver as to make its separation an object of importance. The method pursued is to fuse the copper with lead. As the lead flows out again by subsequent fusion, it brings with it all the silver, and the copper remains behind as a spongy mass. This process is called *liquation*. The silver is then freed from lead by the process of cupellation already described.

Mention some uses of silver.

667. USES OF SILVER.—Most uses of silver are so familiar that they need not be here mentioned. Its employment for daguerreotype plates depends on the fact that the color of many of its compounds is readily changed by light. This subject is more fully considered in the section on Chlorides. The nitrate of silver or lunar caustic, is used in surgical operations, to burn or cauterize the flesh.

In solution, it is also employed as a hair dye, and in the production of indelible ink.

GOLD.

Mention some properties of gold. Its solvent, and occurrence.

668. DESCRIPTION.—Gold is a yellow metal of brilliant and permanent lustre. Its extreme malleability is strikingly illustrated by the fact that it may be hammered into a leaf but little more than $\frac{1}{300,000}$ of an inch in thickness. As the fact may be otherwise stated, a cube of gold five inches on a side could be so extended as to cover more than an acre of ground. Such gold leaf is permeable to hydrogen. A jet of this gas may be blown through it and kindled on the opposite side. Gold is proof against all ordinary acids excepting *aqua-regia*. It is found only in the metallic state, and commonly either in quartz rock or in the sands of rivers. Native gold contains from five to fifteen per cent. of silver.

How is pure gold produced?

669. PRODUCTION.—THE REFINING PROCESS.—Native gold may be freed from the silver which it contains, by the agency of concentrated sulphuric or nitric acid. A difficulty in accomplishing this result arises from the fact that every particle of silver is so perfectly surrounded by gold, that the acid does not readily reach it. This difficulty is overcome by fusing more silver into the gold, and thus opening a passage for the solvent. This being done, both the original silver and that which has been added are readily removed. The above is the process at present pursued in France for refining gold.

Describe another method.

670. ANOTHER METHOD.—The second method is essentially the same as that already described, with the substitution of nitric for sulphuric acid. The addition of silver, as a preliminary step, is found necessary in this process also. So much silver is added, that the gold forms but a *quarter* of the mass exposed to the action of the acid. The method is hence called *quartation*.* The process involves a previous knowledge of the approximate composition of the mixed metal. This may be obtained by the *touchstone*, as hereafter described.

What is amalgamation?

671. AMALGAMATION.—Gold may be obtained from any material which contains it, even in small proportion, by the process of *amalgamation*. This process consists in agitating the finely divided material with mercury, until the latter has extracted all of the precious metal. It is then obtained from its solution in mercury by the same means employed in the case of silver. This method is adopted in the case of the gold-bearing quartz of California. The dust of jewelers shops is similarly treated in order to save the small proportions of gold which it contains.

How is gold separated from lead and copper?

672. GOLD FROM LEAD AND COPPER.—Certain ores of lead and copper contain so much gold that it is profitable to extract it from the metal which they yield. This is done by the processes of *liquation* and *cupellation* before described.

* In the practice of the United States Mint, the addition of *less* silver has been found sufficient. The proportion of gold is there increased to one-third. Nitric acid is then employed in the refining process.

*How is gold
obtained from
certain sul-
phurets?*

673. GOLD FROM SULPHURETS OF IRON, &c.—Sulphurets of iron, copper, &c., sometimes contain gold, in small quantity, and so completely disseminated that it cannot be readily extracted by mercury. It has been found advantageous to heat such ores with nitrate of soda, previous to amalgamation. The sulphurets are thus partially converted into sulphates, which can be washed out. What remains of the pulverized material is at the same time thoroughly opened to the action of mercury.

*Describe the
method of as-
saying gold?
Why is silver
added?*

674. THE GOLD ASSAY.—Gold to be assayed contains commonly only silver and copper as impurities. By fusing the sample with lead and then removing this metal by cupellation, it carries with it the copper, into the cupel. A globule containing only gold and silver remains. The silver is then dissolved out by nitric acid. The remaining sponge of pure gold being weighed, and its weight compared with that of the original sample, the assay is completed. More silver is added in the process, for reasons stated in a previous paragraph.

*What is the
touchstone
and how is it
used in assay-
ing gold?*

675. ASSAY OF GOLD BY THE TOUCHSTONE.—Any hard and somewhat gritty stone of a dark color which is not acted on by acids answers the purpose of a *touchstone*. The assay consists in marking upon the stone with the alloy, and judging of the purity of the metal from the color of the mark, and the degree in which it is affected by an acid. Nitric acid, to which a very

small quantity of muriatic acid has been added, is employed in this test. Gold alone is proof against its action. In proportion to the permanence of the mark, is the purity of the gold which has been submitted to the assay.

What is said of gold coin? 676. GOLD COIN.—The gold employed for coin, plate and jewelry is always alloyed with a certain portion of copper or silver, to give it greater hardness. The standard gold of the United States is nine-tenths pure gold, the remaining tenth being an alloy of copper and silver.

How is the degree of purity of gold expressed? 677. PURITY OF GOLD.—The purity of gold is expressed in *carats*, a carat signifying, practically, one twenty-fourth. Thus, when gold is said to be sixteen carats fine, it is meant that two-thirds of it is pure gold. Gold eighteen carats fine is three-fourths pure gold and one-fourth alloy.

How is copper jewelry gilded? 678. GILDING.—Gilding by the galvanic battery has been already described. This method is, in most cases, preferable to all others. Copper jewelry is thinly gilded by boiling in a solution of gold in carbonate of soda or potash. The solution is prepared by first dissolving the gold in *aqua regia*, and afterward precipitating and re-dissolving it by means of the carbonate above named.

Describe the method of gilding by an amalgam. 679. Gilding may also be effected by an amalgam of gold and mercury. The amalgam being applied, the mercury is expelled by heat and the gold remains. This method is very frequently employed. A coating of pure

gold is produced upon articles of jewelry, made of impure metal, by first heating them, and then dissolving out the copper by means of nitric acid.

PLATINUM.

*Platinum—
Description,
occurrence,
solvents?*

680. DESCRIPTION.—Platinum is the last of the noble metals. It resembles steel in color, and possesses a high degree of malleability. It is the heaviest and the most infusible of all metals. At a white heat it may be welded like iron. Like gold it resists the action of any single acid, but may be dissolved in *aqua-regia*. It is commonly found, like gold, in small flattened grains in the sand of certain rivers. Its pecuniary value is about half that of the more precious metal.

Mention a remarkable effect of platinum on gases.

681. PLATINUM CONDENSES GASES.—The metal platinum has the remarkable property of condensing gases upon its surface, and thereby increasing their affinities.

This effect is in proportion to the surface exposed. It may be prepared for this experiment by burning paper, previously moistened with a solution of this metal. Such an ash, by simple exposure to the air, condenses and retains a large quantity of oxygen within its pores. On holding it in a jet of hydrogen, the condensed oxygen immediately unites with the latter gas so energetically as to inflame it.



Give another illustration of this effect.

682. Platinum is employed for similar purposes, in the form of a sponge, and as a powder, called *platinum black*. A mixture

of nitric oxide and hydrogen, passed through a tube containing heated platinum black, issues from the tube as ammonia and water. The hydrogen has entered into combination with both of the elements of the nitric oxide, producing two new compounds.

Why is platinum superior to other metals for chemical apparatus?

683. OTHER USES OF PLATINUM.—The most important use to which platinum is applied in the arts, is in the manufacture of chemical apparatus. Its extreme infusibility and resistance to acids, adapt it especially to this purpose. In the manufacture of oil of vitriol, for example, no other material excepting gold could well take the place of the platinum vessels in which concentration is effected. Platinum crucibles are also invaluable, as they may be exposed to the fire of a blast furnace without injury. Nothing less than the most intense heat of the oxyhydrogen blow-pipe, or galvanic battery, is sufficient to fuse this metal.

ALLOYS.

What is an alloy? Give the composition of brass and other alloys.

684. The compounds of metals with metals are called *alloys*. The following are among the more important.

Brass is copper lightened in color by the addition of one-fourth its weight of zinc.

German silver is a kind of brass still further whitened by nickel. Its exact composition has been given in another place. An alloy of 30 parts silver, 25 of nickel, and 55 of copper forms a nearly perfect substitute for silver for all ornamental purposes.

Bronze is copper containing ten per cent. of tin. Bell metal is a kind of bronze containing tin in larger proportion.

Pewter is an alloy of tin with variable proportions of antimony or lead. Britannia ware, so called, is a sort of pewter.

Type metal is an alloy of lead containing twenty-five per cent. of copper. By the use of tin, instead of lead, a better, but more expensive type metal may be produced. Zinc, with a few per cent. of copper, lead, and tin, has also been recently employed.

Fine and coarse solders are alloys of tin and lead the former being two-thirds, and the latter one-fourth, tin. Hard solder is a variety of brass.

Newton's fusible metal, which has the remarkable property of melting in boiling water, is composed of 8 parts of bismuth, 5 of lead, and 3 of tin.

Allen's new fusible metal is composed of 1 part cadmium, 1 part tin, 2 parts lead, and 4 parts bismuth. It melts at 150° Fahrenheit.

Many of the above alloys are slightly varied in their character by the addition of other metals in small quantity.

CHAPTER III.

SALTS.

SOLUTION AND CRYSTALLIZATION.

What compounds are called salts?

685. DEFINITION.—Under the general head of salts, are included all compounds of acids and bases, and beside these, the compounds of chlorine, bromine, iodine, sulphur, &c. with the metals. Sulphate of copper or blue vitriol is an example of the first class, and chloride of sodium or common salt of the latter.

Mention some methods of preparing salts.

686. PREPARATION OF SALTS.—The salts of most acids may be produced by simply bringing the acid and oxide together. Sulphate of potassa is thus produced from sulphuric acid and potassa. Heat is sometimes required to bring about the combination. They may also be prepared from the carbonates. Thus acetate of lime, is produced by pouring strong vinegar on chalk, or carbonate of lime. Carbonic acid is in such cases expelled by the stronger acid which is employed. Other methods of preparing individual salts will be hereafter given.

Explain solution.

687. SOLUTION.—The particles of all bodies are held together, as before explained, by the attraction of cohesion. But water has

also an attraction for these particles. In the case of many substances, it overcomes the force of cohesion and distributes them throughout its own volume. Such a distribution, in which the solid form of the solid is entirely lost, is called *solution*. Different liquids are employed as solvents for different substances. A solution is said to be *saturated* when no more of the solid will dissolve in it.

Have the particles lost their cohesive attraction? how may they be precipitated?

688. PRECIPITATION.—In solution, the particles of bodies have not lost their property of cohesive attraction. It is only overcome by a superior force. As soon as this is weakened they unite again to form a solid. The solvent power of alcohol for camphor, is thus diminished when water is added to the solution. As a consequence, the camphor immediately re-assumes the solid form. When a solid is thus re-produced as a liquid, it is called a *precipitate*. The above experiment is made by adding water to an ordinary solution of camphor.



Mention two general methods of precipitation.

689. One case of precipitation is mentioned in the preceding paragraph. But it may be effected by various methods. All of these may be arranged under two heads; precipitation *by changing the character or quantity of the solvent*, and precipitation *by changing the substance dissolved*.

Mention three cases of precipitation by change of solvents?

690. CHANGE OF SOLVENT.—The three cases in which precipitation is effected by changes in the solvent, are, *mixing*, *cooling*, and *evaporation*. The first has just been

described. The second is illustrated in the production of alum crystals by cooling a hot solution. The third consists in dissolving a solid in some liquid and then boiling away the latter. The experiment may be tried with a saturated solution of salt and water. As fast as the water is boiled away, the portion which has lost its solvent re-assumes the solid form.

691. CHANGE OF SUBSTANCE DISSOLVED.

Describe two cases by change of substance.

The change in the substance dissolved, is effected in some cases by addition, and in others by subtraction. Carbonic acid blown through lime water precipitates it by addition. The precipitate is chalk or carbonate of lime. Potash added to a solution of sulphate of copper, precipitates it by subtraction; the precipitate is oxide of copper, deprived of its acid by the potash.

692. EXPLANATION.—The above cases

State the cause of precipitation in the above cases.

of precipitation demand some further explanation. As fast as carbonic acid is blown into the lime water, in the first case, the new substance chalk or carbonate of lime is produced throughout the liquid. We may suppose that innumerable particles are first formed, before they unite to form a precipitate. But the cohesive attraction put forth by the particles of this new compound is so great that the opposing attraction of the water is overcome, they rush together, and assume the solid form of a precipitate. This did not happen in the case of lime alone, because the cohesive attraction between its particles is inferior to the opposing attraction of the water. The second case is to be similarly explained.

*What is said
of the relation
of cohesion
and affinity?*

693. RELATION OF COHESION AND AFFINITY.—The chemical affinity of potassa for carbonic acid is evidently greater than that of lime. The former base retains the acid so firmly that no degree of heat can effect it, while the latter gives up its acid with readiness, under the influence of a high temperature. Notwithstanding the superior affinity of potassa, lime will take from it its carbonic acid, if added to a solution of carbonate of potassa in water. The mixture being made, the particles in this and in all similar cases tend to re-arrange themselves in the solid form. They seem to do this without reference to their chemical affinities, in such a manner as best to resist the solvent action of the water or other liquid. Carbonate of lime resists such action better than carbonate of potassa. The former is therefore produced. The *cohesion* of carbonate of lime, using the term in the sense of capacity to resist the separating power of water, has therefore determined the production of this substance in opposition to ordinary chemical affinities.

*State and il-
lustrate the
general law.*

694. The above case illustrates a general law. Two substances, which when united form an insoluble compound, generally unite and produce it, when they meet in solution. To illustrate by another example: phosphate of lime or bone ash is insoluble. Therefore we may be sure that phosphoric acid and lime, if brought together by mixing two solutions, will desert any substances with which they were before combined, and unite to form insoluble phosphate of

lime. This rule is not without exceptions, but it enables the chemist to determine beforehand innumerable cases of precipitation.

How does solution differ from chemical combination?

695. SOLUTION AND CHEMICAL COMBINATION.—Solution differs from chemical combination in the varying proportions in which it occurs according to temperature, and in the absence of any change of chemical properties. Nitre, for example, dissolves in water at 100°, in nearly double the quantity which will dissolve at 70°. At the same time, it forms a solution to which it has imparted its own chemical properties unchanged.

State another important distinction.

596. Another important distinction is found in the following fact. While chemical combination is most active between bodies whose properties are most opposed, such as acids and bases, solution occurs most readily in the case of *similar* substances. The metals dissolve in mercury. Salts dissolve in water. Fats and resins dissolve in alcohol and ether, which, like themselves, contain much hydrogen.

What is said of crystalline arrangement?

697. CRYSTALLIZATION.—In passing from the liquid to the solid condition, the particles of most bodies assume a crystalline arrangement. Their mutual attraction is more than a mere force which draws and binds them together. It groups them in regular forms. The crystals thus produced are often too small to be separately seen. But even where this is the case, the crystalline structure is readily observed. Surfaces of zinc or cast iron ex-

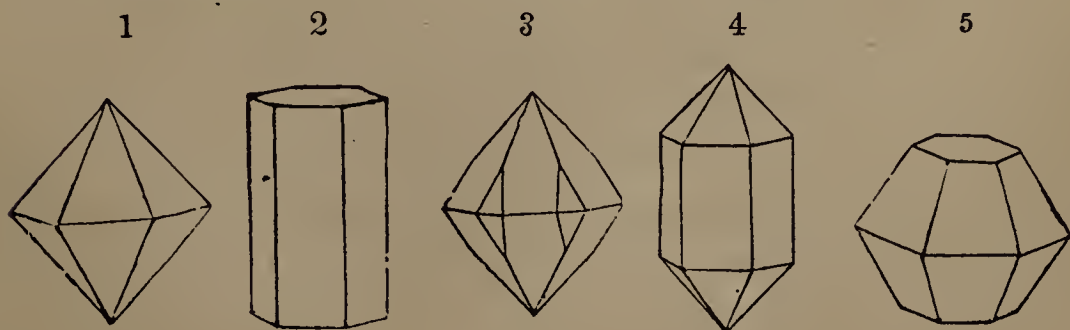
posed by recent fracture, are familiar examples. But where the circumstances are favorable for the formation of individual and separate crystals, the most beautiful and symmetrical forms are often the result.

*How may
crystals be
produced?*

698. PRODUCTION OF CRYSTALS.—Most of the salts to be described in this chapter may be obtained in the form of crystals by evaporating or cooling their saturated solutions. The method by cooling has already been described in the chapter on Water. In obtaining crystals by evaporation, the solution is to be moderately heated in a saucer or other vessel. The crystals formed by either method commonly contain water, which becomes part of the solid crystal, and is called water of crystallization.

*How may the
variety of
crystals be il-
lustrated?*

699. VARIETY OF CRYSTALS.—The forms of leaves and flowers are scarcely more various than those of crystals. The latter are, as it were, the flowers of the mineral world, as distinctly characterized in their peculiar beauty as the flowers that bloom in the air above them. Even where color fails, the eye of science distinguishes peculiar features which often enable it to determine the nature of a substance from the external crystalline form which it assumes.



*What is said
of the variety
of forms in a
single sub-
stance?*

700. FORMS OF CRYSTALS.—As every flower has its own distinctive form of leaves and petals, so every substance has its own form or set of forms from which it never essentially varies. Among these or its combinations, it is, as it were, left free to choose in every crystal which it builds. The mineral quartz, which caps its prismatic palace with a hexagonal pyramid, is an example. Its common form represented in Fig. 4, is a combination of the prism and double six-sided pyramid, which commence the series.

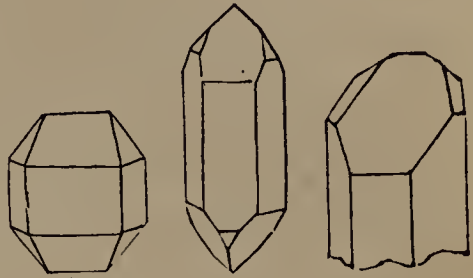
*Describe some
forms of a
single set.*

701. A form similar to the double six-sided pyramid, with faces corresponding to its twelve converging edges, belongs to the same set. Double pyramids similar to each of these, but of one-half or one-third their relative height, or differing from them by some other simple ratio, also belong to the same set of forms. Fig. 3 represents a form composed of two of these pyramids. Fig. 5 represents another form in which one of them is modified by two faces of a prism. To all of these and certain other intimately related forms, the imaginary privilege of selection and combination, above referred to, extends. But most substances, like quartz, as above described, affect some particular shape or combination in which they usually appear.

*What modifi-
cations of the
same form
may occur?*

702. MODIFICATIONS OF CRYSTALS.—Whatever the form or combination may be, it is susceptible of variation, in any degree, so long as its angles correspond to those of the perfect shape. Thus the mineral quartz, in its

commonly occurring combination, is not restricted to a perfectly symmetrical shape, like that above presented. It may develop one surface and diminish the others to any extent. Forms such as are represented in the margin result. Different as they seem, it will be observed that they agree precisely with the perfect shape in the angles between the surfaces of the prism and pyramid, and the different surfaces of each. In this their identity as crystalline forms consists. It would thus seem that nature pays exclusive attention to the corners and angles in her various systems of crystalline architecture.

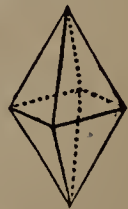


What constitutes a new set?

703. The least variation of the relative length of the vertical axis that is not by some simple ratio, constitutes a new and distinct form. This has its related forms as before, the whole making a new and distinct set, to which the choice of any substance that enters it is limited.

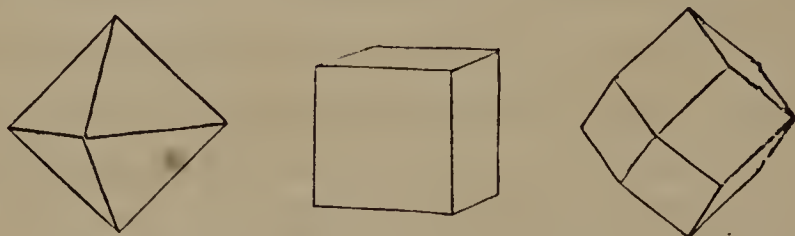
Define another system of crystalline forms.

704. SYSTEMS OF CRYSTAL FORMS.—It will be obvious to the student that the substitution of an octahedron, such as is represented in the accompanying figure, for the double six-sided pyramid, would be the starting point of an entirely distinct system of forms. Within its limits there might be innumerable sets as before. It would be, as it were, the type of a new order of crystalline architecture, susceptible of variations consistent with the general style.



Define the third and fourth systems.

705. A third system is characterized by inequality in three principal dimensions. The axes or lines connecting the solid angles in the octahedron, and joining the faces in the prism, are all unequal. As each axis may be indefinitely varied in this system, there is room within its limits for still greater variety than before. The fourth system differs from the third in an oblique position of some one of the unequal axes. The student will readily imagine certain oblique forms which it includes. The fifth system is characterized by an oblique position of three unequal axes.*



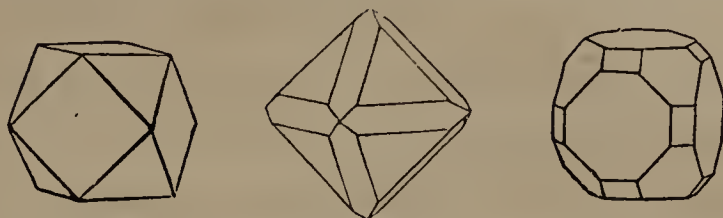
What are the characteristics of the regular system?

706. The regular system, which is properly the first, has all its axes equal and all its angles right angles.† The figures which precede this paragraph represent some of its simpler forms. Those which follow, are among its most interesting combinations. In the last, the student will be able to select three distinct kinds of surfaces. One of these sets, if enlarged to the exclusion of the others, would produce a cube,

* The variations of length and inclination of axis which correspond to the different systems, may be beautifully illustrated to the eye by a wooden frame work movable at the centre with threads connecting the arms.

† The first and sixth systems are made to change places in the above arrangement, for the convenience of illustration from the quartz crystal.

another a regular octahedron, and a third a dodecahedron ; forms corresponding to those of the preceding line.



In view of its simplicity, the regular system may be regarded as a sort of primitive architecture, yielding, however, to no other system in the beauty of its forms. Under one or the other of these systems all forms of crystals are included. To each of them, with the exception of the last, belong innumerable sets of forms according to the degree of inequality or inclination of the axes. Equality and rectangular position of the axes being characteristic of the first system, it is not susceptible of the sort of variation which is essential to produce different sets of figures. But in this, as in other systems, the modification of surfaces may occur to any extent.

Show how the form of a crystal may be inferred from its angles.

707. As the architect is able, from some relic of a broken column, to build up in imagination the temple of which it formed a part ; as the comparative anatomist knows how, from the fragment of a single bone to reconstruct in imagination the perfect animal which possessed it ; so, from the merest point of a crystal, its complete form may often be readily inferred. In proportion as a double pyramid is lengthened out, the angles above and below are rendered more acute. From an accurate admeasurement of this angle its whole shape may therefore be inferred. Such admeasurement of various an-

gles is employed not alone as a means of inference of perfect from imperfect shapes, but as the simplest means of accurate description. For, as before stated, it is the size of the corresponding angles of a crystal which form its characteristic.

Have different substances ever the same crystalline form?

708. ISOMORPHISM.—Many substances which are alike in the number and arrangement of their atoms, although these atoms are different in kind, have the same crystalline form. This is the case with common alum and other alums to be hereafter mentioned. The similar arrangement of atoms will be best seen by inspecting the formulæ which represent them. These are given in the appendix. The term expresses their likeness in form. Besides this series there are many other isomorphous groups.

Give the probable reason.

709. It is to be regarded as probable, that the shape and size of the molecules thus similarly composed is exactly the same, and that it is for this reason that they may be used in building up crystals of the same form. The different alums will even unite when they crystallize in building up one and the same crystal. Substances which are thus similar in composition and crystallize in the same form, are called *isomorphous*. There are many cases of similar crystalline form in substances which are not thus related in other respects. Such bodies are not called isomorphous, notwithstanding their identity of crystalline form. Certain substances crystallize in forms belonging to two or even three different systems, according to the temperature, or other circumstances under which their crystallization occurs. Such substances are called *dimorphous* or *trimorphous*.

OXIDES.

Define an oxide. By what terms are different oxides distinguished?

710. The compounds of the metals with oxygen, with the exception of those which have decidedly acid properties, are called *oxides*. When a metal unites with oxygen in several different proportions, forming different oxides, these are distinguished as *protoxide*, *deutoxide* or *binoxide*, *tritoxide* or *teroxide*: terms signifying first, second, and third oxides. The highest oxide is also called *peroxide*. An oxide containing three atoms of oxygen to two atoms of metal, is called a *sesquioxide*. The names of chlorides, sulphurets, &c. are similarly modified, to indicate the proportion of chlorine, sulphur, &c. which they respectively contain. Compounds of non-metallic substances with oxygen which do not possess acid properties, are also called oxides. There are, for example, oxides of nitrogen and phosphorus.

What is said of acid and basic properties in oxides?

711. PROPERTIES OF OXIDES.—The lower oxides are generally strong bases, while the higher oxides exhibit basic or acid properties according to circumstances. Binoxide of tin, for example, described in a previous chapter, acts as a base in combining with sulphuric acid to form a sulphate, while, if fused with potassa, it acts as an acid and forms a stannate. On account of its acid property, the binoxide of tin is also called stannic acid. The name is derived from *Stannum*, which is the Latin word for Tin.

How are oxides formed? Give examples.

712. FORMATION OF OXIDES.—Oxides may be formed directly by the union of oxygen and metal, or, indirectly, by separating them from some salts which contain them. Thus oxide of copper may be produced by simply heating copper in the air; or, by precipitation from the nitrate, through the agency of potassa, or, thirdly, by simply heating the nitrate till all the acid is expelled. The oxides of tin and antimony are also directly produced, by the action of nitric acid on the metals.

What is a hydrated oxide?

713. HYDRATES, OR HYDRATED OXIDES. Oxides commonly combine in the act of precipitation with a certain proportion of water. The compound thus formed are called hydrated oxides, or simply *hydrates*. The water may, in most cases, be separated from them by heat, and the uncombined oxide thus obtained.

What is said of the conversion of oxides?

714. CONVERSION OF OXIDES.—When oxides are converted into chlorides, sulphurets, &c., by double decompositions, to be hereafter described, the chlorides, sulphurets, &c., correspond to the oxides from which they are formed. Thus, protoxide of iron yields protochloride, while sesquioxide yields sesquichloride.

Give some properties of the alkalies.

715. THE ALKALIES.—The oxides of potassium and sodium are called *alkalies*. They are known as potassa and soda, and are commonly obtained as hydrates. They are white infusible substances from which the water cannot be expelled by heat. They are soluble in water.

and are the strongest of all bases. From their destructive action on animal matter, they are called *caustic alkalies*, and are often distinguished by this term from the carbonates of potassa and soda.

POTASSA.

What is the source of potassa? 716. Potassa is prepared from wood ashes. The ley obtained from these being evaporated to dryness, the mass which remains is the crude potash of commerce. This, when purified, becomes *pearlash*.

How is potassa prepared? 717. CAUSTIC POTASSA.—Commercial potash and pearlash are both carbonates of potash, from which the carbonic acid must be removed, in order to produce potassa itself. This is done by a milk of slaked lime. A solution of potash in at least ten parts of hot water, or a hot ley, made directly from wood ashes, should be employed in the experiment. To this the milk of lime is added, little by little, the solution boiled up after each addition, and then allowed to settle. If, after settling, a portion of the clear liquid is found no longer to effervesce on the addition of an acid, it is sufficient evidence that all the carbonic acid has been removed by the lime, and the process is completed. This must be ascertained by trial. About half as much lime as potash will be required in the process. Caustic soda is similarly made from the carbonate of soda.

Give a modification of the above method. 718. The boiling in the above process may be omitted, if the mixture be frequently shaken up during several days.

This modification of the method is much the most convenient for the production of caustic alkalies in small quantities. Solutions, useful for a variety of chemical purposes, are thus obtained, and should be preserved for use. They may be converted into solids by evaporation, and the solid thus obtained fused and run into moulds. The commercial caustic potassa, occurring in slender sticks of white or grey color, is thus produced.



How can the affinity of potassa for water be proved?

719. AFFINITY OF POTASSA FOR WATER.

Ordinary potassa, as before stated, is a hydrate. But its affinity for water is by no means yet satisfied in this form. If exposed in an open vessel, it rapidly attracts moisture from the air. It often dissolves, in the course of a few days, in the water thus obtained.



What is said of the decomposition of salts by potassa?

720. DECOMPOSITION BY POTASSA.—

Potassa added to the solution of almost any salt occasions a precipitate. The potassa takes the acid and precipitates the insoluble base. If the experiment is made with an ammonia salt, the base being volatile passes off into the air. Experiments may also be made with green, blue, and white vitriols, which are, respectively, sulphates of iron, copper, and zinc.

Illustrate the cleansing properties of potassa?

721. CLEANSING AND CAUSTIC PROPERTIES OF POTASSA.—

If soiled rags are boiled with a dilute solution of potassa, they will be thoroughly cleansed by the process.

The potassa unites with the acid of the grease contained in the cloth, and thus makes it soluble in water.

What is the action of potassa on animal matter? 722. ACTION OF POTASSA ON ANIMAL MATTER.—Potassa is extremely destructive of animal matter. It readily dissolves the skin, as may be proved by rubbing a little between the fingers. If applied in sufficient quantity, it destroys the vitality of the flesh. It is often used for this purpose by surgeons.

How does potassa affect vegetable colors? 723. EFFECT ON VEGETABLE COLORS.—Vegetable blues which have been previously reddened by acid, are restored to their original color by the action of potash and other alkalies. The blue pigment called *litmus* is the one most readily obtained. In preparation for the experiment, it is infused in hot water. The transformation from blue to red and *vice versa* may be repeated as often as desired, by the alternate addition of acid and alkali. Paper soaked in the red and blue liquids forms the *test-paper* of the chemist. It is used to indicate the presence of smaller quantities of acid and alkali than could be recognized by the taste. An extract of purple cabbage leaves, or the leaf itself, may be used in the above experiment. In this case the change of color by alkalies is from red to green.

What of the properties of soda? 724. PROPERTIES OF SODA.—The properties of soda are very similar to those of potassa, as above described.

OXIDE OF AMMONIUM.

What is said of oxide of ammonium? 725. FORMATION.—When hydrated sulphuric acid combines with ammonia, the water which it contains is regarded as converting the ammonia into oxide of ammonium, with which the acid then combines. The action of other hydrated acids is the same. In naming the corresponding salts, the oxide of ammonium is called ammonia. Thus, the compound with sulphuric acid, is called sulphate of ammonia. It is to be borne in mind, that oxide of ammonium of such salts, contains a molecule of water in addition to the constituents of ammoniacal gas.

OXIDE OF CALCIUM.

How is lime obtained? 726. LIME.—Lime or oxide of calcium is best obtained by heating chalk, marble or limestone. These are all carbonates of lime. Under the influence of a high temperature, the tendency of the carbonic acid to assume the gaseous form is so increased, that the chemical affinities of the base are overcome. The carbonic acid escapes, leaving the caustic lime behind. This is the process of the ordinary lime kiln. The superior strength of potassa and soda as bases, is illustrated by the fact that the carbonic acid cannot be removed from them through the agency of heat.

What is hydrate of lime? 727. HYDRATE OF LIME.—SLAKED LIME. When water is added to lime, one equivalent immediately combines with it and

forms a hydrate. The hydrate, like that of potassa, is dry, although it contains a large portion of combined water. As the water thus becomes solid in the compound, its latent heat is given off to the air or surrounding objects. The employment of heat thus produced for culinary operations has been recently suggested. If the process of slaking is conducted under a tumbler, with a slight surplus of water, steam will be produced. On lifting the tumbler, it will become visible by its condensation into vapor.

How may gun-powder be ignited through the agency of lime? 728. IGNITION BY LIME.—The heat thus produced is often sufficient to ignite gun-powder. It should be sprinkled on the mass and kept dry while the slaking proceeds. Warm water and well-burned lime should be employed in the experiment.

What is the action of the air on lime? 729. ACTION OF THE AIR.—If lime is exposed to the action of the air, it gradually combines with carbonic acid and water, and becomes converted into a mixture of hydrate and carbonate. It is then called air-slaked lime. By sufficiently long exposure the conversion into carbonate is complete.

Why does mortar harden? 730. LIME IN MORTAR.—Ordinary mortar is a mixture of sand and lime. It hardens not simply by drying, but by the absorption of carbonic acid from the air. A compound of hydrate and carbonate of lime, possessed of great hardness, is thus produced. A gradual combination also takes place between the silica and the lime, which binds the two constituents still more firmly together.

What is hydraulic cement?

731. **HYDRAULIC CEMENT.**—If, in the preparation of lime, a limestone is used which contains a certain proportion of clay, a double silicate of alumina and lime is produced. The compound has not alone the property of combining with water, like ordinary lime, but of becoming extremely hard and insoluble in the process. Such a lime is called *hydraulic cement*, and is used for building under water. Silica, magnesia, and some other substances impart the same property to lime.

ALUMINA, MAGNESIA, &c.

What is alumina?

732. **ALUMINA, &c.**—Alumina, so named from the corresponding metal, is insoluble, and is called an *earth*. It is, like the peroxide of iron, a sesquioxide, containing three atoms of oxygen to two of metal. Natural alumina colored blue is called sapphire. Colored red it forms the oriental ruby. The topaz and the emerald are also compounds containing the same oxide. Baryta, strontia, lime and magnesia, are regarded as standing midway between the earth alumina and the alkalies and are called *alkaline earths*. They are more or less soluble, and possess the general properties of the alkalies in a diminished degree. Magnesia is sometimes classed as an earth.

What are the properties of the other metallic oxides?

733. **OTHER METALLIC OXIDES.**—The remaining metallic oxides are powders of different colors. Most of them are insoluble. The more important have been already noticed in the Chapter on Metals. Their

hydrates may be obtained by precipitating solutions of their salts with potassa, soda, or ammonia. The hydrate of the oxide of copper and peroxide of iron may serve as examples. The former is blue and the latter a reddish brown.

Which hydrated oxides dissolve in ammonia? 734. The hydrated oxides of nickel, cobalt, tin and copper, produced from solution of these metals by the addition of ammonia, are again re-dissolved in an excess of ammonia. That of copper dissolves with a beautiful blue color, which is conclusive evidence that the liquid with which the experiment is made contains copper in solution.

Give the uses of some of the oxides. 735. Uses.—Oxide of magnesium or magnesia, and mercury, among others, are used in medicine, and white oxide of zinc, as a paint. Litharge or protoxide of lead is employed in making flint-glass and varnishes. Red lead is used as a paint. Oxide of bismuth is employed as a cosmetic.

What color is produced in glass by the oxide of manganese, cobalt, copper, iron, &c., &c.? 736. Oxide of manganese is used to color glass purple and violet. Oxide of cobalt, to color it blue; oxides of copper, and chromium, to impart a green color to glass and porcelain; peroxide of iron, to give it a yellowish red, and protoxide, a bottle-green. Sub-oxide of copper gives to glass a beautiful ruby red. Silver and antimony are employed to produce different shades of yellow and orange. Violet and rose color are obtained by means of the *purple of Cassius*, a beautiful purple precipitate, containing

tin and gold, and prepared by adding protochloride of tin to a gold solution.

How may these effects be illustrated?

737. GLASS STAINING.—The effect of oxides, above mentioned, in coloring glass, may be illustrated by fusing them into a borax bead. The bead is to be formed with the aid of the blow-pipe, in a loop of platinum wire. In the absence of such wire, the borax glass may be made upon the surface of a pipe bowl. Instead of employing the oxide, it is generally more convenient to moisten the bead with a very small quantity of a solution of the metal. In order to obtain good colors, the quantity of coloring material employed must be very small.



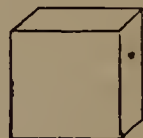
How is glass and porcelain stained superficially?

738. For staining glass and porcelain superficially, a colored and easily fusible glass is first prepared with borax or some analogous material. This being ground up and applied as a paint, is afterward baked into the surface. Several of the oxides mentioned in a preceding paragraph are thus employed.

CHLORIDES.

Describe some of the properties of chlorides.

739. DESCRIPTION.—The chlorides are, for the most part, soluble salts, of colors corresponding to the solutions of the metals from which they are produced. Common salt may stand as a type of the class. Chloride of silver and subchloride of mercury or calomel are insoluble; the chloride of lead is but slightly soluble in water.



How are chlorides made from metals? Give examples.

740. PREPARATION.—Chlorides may be made by the action of chlorine or hydrochloric acid on the metals. The combustion of antimony in chlorine gas, the solution of gold in *aqua regia*, and that of zinc in hydrochloric acid are examples. The chemical action in each of these cases has been explained in previous chapters. The solutions being evaporated, the chlorides are obtained in the solid form. The solution of zinc in hydrochloric acid is a case of *single elective affinity*: the metal elects or chooses the chlorine.

How are chlorides produced from oxides?

741. Chlorides may also be formed by the action of hydrochloric acid on oxides. Thus common salt or chloride of sodium may be made by mixing hydrochloric acid and soda. The hydrogen of the acid and the oxygen of the soda unite to form water, while the chlorine of the acid and the metal sodium unite to form the chloride. This is a case of double decomposition, resulting from *double elective affinity*. The chloride commonly corresponds to the oxide from which it is produced. Thus soda, which is a *protoxide*, yields common salt, which is a *protochloride*. Again, sesquioxide of iron, containing three atoms of oxygen to two of metal, yields sesquichloride of iron containing the same proportion of chlorine.

How are the insoluble chlorides obtained directly in a solid form?

742. The insoluble chlorides may be obtained directly in a solid form by a similar double decomposition. Thus, chloride of sodium and oxide of silver in solution,

yield, when mixed, a precipitate of *chloride of silver*; newly-formed oxide of sodium or soda remains in solution. The latter unites with the acid originally employed to dissolve the oxide of silver. This is commonly nitric acid.

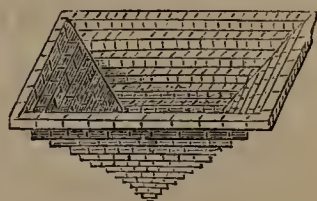


From what sources is common salt obtained? 743. CHLORIDE OF SODIUM.—COMMON SALT.—Common salt is found in great abundance in Poland and other countries, as Rock salt, which is regularly mined like coal. It is also obtained by evaporating the water of the sea or salt springs, in the sun or by artificial heat. When the salt water is boiled down the salt separates in crystals, while the impurities remain in the small portion of liquid which is not evaporated. These consist principally of chloride of magnesium and other salts. Contrary to the general rule, salt is equally soluble in cold and hot water.

How is salt produced from very weak brine? 744. When salt is to be made from water which contains it in very small proportion, it is a frequent practice in Europe, to pump the weak brine to the top of large heaps of brush, and allow it to trickle through them. The object of the method is to produce a large evaporating surface. The air, as it passes through the heaps, carries away a large part of the water and leaves the salt behind. The strong brine which is collected below is then boiled down, as before described. The annual produce of the salt springs at Syracuse, New York, exceeds 5,000,000 bushels.

How may crystals of salt be obtained?

745. Beautiful crystals of common salt may be obtained by gradually evaporating a saturated solution. This will be accomplished by keeping it for some time moderately warm, on a stove or in the sun. The crystals are shaped as represented in the figure, and are made of innumerable small cubes, which build themselves regularly upon the edges as the larger crystals sink little by little into the solution.



How does salt act to preserve flesh?

746. USES OF COMMON SALT.—The use of common salt in preserving the flesh of animals from decay, depends in part on the fact that it extracts from the flesh a large proportion of water. It thus, to a certain extent, dries them. This action will be immediately observed if a little salt is sprinkled upon flesh. It will speedily draw out the juices of the meat and itself disappear by dissolving in them.

How much salt is contained in sea water? in the water of the Dead Sea?

747. SEA WATER.—Every pound of sea water contains from one-half to five-eighths of an ounce of salt. The greater part of this is chloride of sodium or common salt. The water of the Dead Sea contains a much larger proportion, and is more than an eighth part heavier than pure water. Owing to its greater density, a muscular man floats breast high in it without the least exertion. Fresh eggs, which sink in sea water, float in that of the Dead Sea with one-third of their length above the surface.

*On what does
the value of
chloride of
lime depend?*

748. CHLORIDE OF LIME.—BLEACHING POWDER.—The commercial article of this name is prepared by passing chlorine gas over lime. It is a white powder with an odor similar to that of chlorine gas. Its value depends on the fact that the gas is thus brought into a solid form and made capable of transportation. It may be released again by the simplest means, to be used as a bleaching and disaffecting agent. The addition of an acid, as has been seen in the chapter on Chlorine, is all that is necessary to effect this object. It occurs, indeed, spontaneously in the moistened powder, through the action of the carbonic acid of the air.

*How may its
properties be
illustrated?*

749. ILLUSTRATION.—To illustrate its bleaching power, a strip of calico may be soaked in a solution of the chloride, and then in acid water. Nascent chlorine is thus liberated in the fibre of the cloth, and is more effectual than if otherwise applied.

*How are its
elements com-
bined?*

750. FORM OF COMBINATION.—The chemical action which occurs in the formation of chloride of lime is as follows. The chlorine combines with both constituents of the lime forming with its metal chloride of calcium, and with its oxygen, hypochlorous acid. This acid combines as it is produced with another portion of lime forming a salt. Bleaching powder is therefore a mixture of chloride of calcium and hypochlorite of lime, with a certain proportion of lime still uncombined. The name *chloride of lime* has no chemical propriety. The mixture is, practically, chlorine and lime, for as soon as an acid is

added, all of the original lime is re-formed and chlorine is evolved.

How is chloride of aluminium prepared? **751. CHLORIDE OF ALUMINIUM.**—This salt is of peculiar interest and importance, in view of its employment in the preparation of the new metal aluminium. It is prepared by heating alumina at the same time with carbon and chlorine. The alumina is torn asunder, as it were, by the affinities which are thus brought into play. The carbon takes its oxygen and passes off with it as carbonic oxide, while the chlorine takes the metal and escapes with it as volatile chloride of aluminium. The carbon in the process is supplied by coal tar. The process is conducted in iron retorts, the materials having been previously ignited together before their introduction.

How is it purified? **752.** The chloride is impure, from the presence of volatile sesquichloride of iron. This is separated by leading the uncondensed vapors over highly heated points of iron. The iron has the effect of removing part of the chlorine from the sesquichloride of iron and reducing it to a non-volatile protochloride. It is thus stopped in its course, while the chloride of aluminium passes on unaffected. It condenses in the cooler part of the apparatus, in the form of colorless transparent crystals.

What is said of colored flames? **753. COLORED FLAMES.**—A series of beautiful flame experiments may be made with the chlorides. The flame of alcohol assumes different colors according to the chloride employed. Chloride of sodium or common salt gives

a yellow ; chloride of potassium, violet ; chloride of calcium, orange ; chloride of barium, yellow ; chloride of copper, blue.



Instead of the chlorides, other soluble salts may be employed with the addition of a little hydrochloric acid. A beautiful green may be obtained from a copper coin moistened with strong nitric acid, with the use of alcohol as before. The colors of fireworks are similarly produced by the addition of the above and certain other salts.

*What is said
of other chlo-
rides ?*

754. OTHER CHLORIDES.—The other chlorides are not of sufficient general interest to be here particularly described. Corrosive sublimate, the uses of which are mentioned in the chapter on Mercury, is a chloride of this metal. Calomel is a subchloride of the same metal.

IODIDES, BROMIDES AND FLUORIDES.

*What is said
of the iodides
and bromides ?*

755. The iodides and bromides are classes of salts analogous to the chlorides. Those of potassium, used in medicine and in photography, are the most important.

*How is the blue
iodide of
starch pre-
pared ?*

756. DETECTION OF $\frac{1}{1000000}$ IODINE.—A beautiful blue is prepared by adding a little chlorine water and starch paste to a solution of iodide of potassium. The chlorine sets iodine at liberty, which then combines with starch to form the blue compound. By this test iodine can be detected in a liquid which contains but a

millionth part of this element. By the substitution of bromide of potassium in the experiment, an orange color is produced.

How is this experiment employed as a test for chlorine?

757. TEST FOR CHLORINE AND IODINE.—

The experiment may also be made by moistening a slip of paper with starch and iodide of potassium, and holding it in an atmosphere containing a little chlorine gas.

An extremely small quantity of chlorine is thus indicated, and the prepared paper thus becomes a test for chlorine. Such paper is also used to show the presence of ozone in the air.



What is said of the iodide of mercury?

758. CHANGE OF COLOR BY HEAT.—By mixing solutions of iodide of potassium and corrosive sublimate or chloride of mercury, a beautiful scarlet iodide of mercury is produced. On heating the dried precipitate it becomes yellow. The experiment is best made with two watch glasses. The iodide is heated in the lower one and collects by sublimation, with changed color, in the upper.

What effect is produced by touching the yellow incrustation?

759. CHANGE OF COLOR BY TOUCH.—

On touching the yellow incrustation with the point of a needle, it is immediately stained scarlet at the point of contact. The

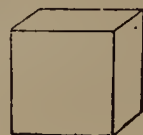
color gradually spreads, as if it were a contagious disease, through the whole mass, until every particle has regained its original scarlet. This experiment furnishes a very remarkable instance of change of an important property without change of composition. As

the change of color proceeds, the small scales of which the yellow iodide is composed break up into octahedrons. The change of color is regarded as a consequence of the re-arrangement of atoms, which produces the change of form.

FLUORIDES.

*What is said
of fluor-spar?*

760. FLUOR-SPAR.—The fluorides, with the exception of those of the alkalies, are for the most part white insoluble compounds. The only one of especial interest, is the beautiful mineral known as *fluor-spar*. This mineral is a fluoride of calcium. It is found of white, green, purple and rose color, crystallized in regular cubes or octahedrons. Hydrofluoric acid, which has the remarkable property of etching glass, as before described, is prepared from it.



SULPHURETS.

Define a sulphuret.

761. The compounds of the metals with sulphur are called *sulphides* or *sulphurets*. They are of various colors, and, for the most part, insoluble. Iron pyrites and galena or sulphuret of lead, are examples.



The figure represents a crystal of *magnetic pyrites*, which is one of the sulphurets of iron. The form belongs to the sixth or hexagonal system.

How are sulphurets generally prepared?

762. PREPARATION.—Most of the sulphurets may be produced by adding hydro-sulphuric acid to solutions of the different metals or their salts. Sulphur and metal

unite and precipitate, while the hydrogen and oxygen, previously combined with them, form water.

Mention the colors of some of the sulphurets.

763. The sulphuret of zinc is white; that of arsenic, yellow; and that of antimony, orange. The remainder of the insoluble sulphurets are black. Solutions of white vitriol, arsenious acid, and tartar emetic may be used, as above directed, to produce sulphurets of zinc, arsenic and antimony. If the zinc precipitate should be colored, it is owing to the presence of iron in the salt, as impurity. Blue vitriol may be employed to produce black sulphuret of copper.



What is said of the sulphurets of the alkalies?

764. The sulphurets of ammonium, potassium and sodium cannot be precipitated by this process. Being soluble, they remain in the liquid. Solutions of the caustic alkalies are to be used in preparing them. The solutions of these sulphurets are useful, as they may, in many cases, be substituted with advantage for hydro-sulphuric acid in precipitating sulphurets from solutions of other metals. Certain other sulphurets are soluble and do not precipitate, as will be seen from the table in the Appendix.

What is liver of sulphur? How is it prepared?

765. LIVER OF SULPHUR.—There are a number of sulphurets of potassium, containing each a different proportion of sulphur. That which contains five atoms of sulphur to one of metal is called, from its peculiar color, *liver of sulphur*. It is prepared by boiling flowers of sulphur in a strong solution of potash. It may also

be made by fusion of the same materials. The proto-sulphuret can be made from the sulphate, by reduction with hot carbon. Certain other soluble sulphurets may be produced in the same manner.

How is milk of sulphur prepared? 766. MILK OF SULPHUR.—This form of sulphur, like that just mentioned, is used in medicine. It may be prepared from a solution of the liver of sulphur, by the addition of an acid. The latter combining with the potassa, the sulphur is precipitated in a state of the finest division, giving to the liquid the appearance of milk.

What is said of the other sulphurets? 767. OTHER SULPHURETS.—The natural sulphurets have colors different from the similar compounds when produced, as above, by precipitation. Thus, the natural sulphuret of lead or *galena* has the color of the metal; that of mercury is red, and is called cinnabar; that of zinc, called *zinc blende*, and by miners *black jack*, is of different shades—brown, yellow and black. The precipitated sulphuret of mercury turns red by sublimation, and in this state forms the familiar pigment called *vermilion*. Sulphuret of iron, which is employed in making hydrosulphuric acid, may be prepared by holding a roll of sulphur against a rod of iron previously heated to whiteness. This may be readily done in any blacksmith's shop. The fused sulphuret falls in globules from the surface of the iron.

SULPHATES.

*What is said
of the color
and solubility
of sulphates?*

768. The sulphates, with the exception of those of the alkaline earths, are, for the most part, soluble salts. They are similar in color to the solutions of the corresponding metals. The figure represents a crystal of gypsum. The form belongs to the fourth system.



*How are the
sulphates
formed?*

769. PREPARATION.—The sulphates are produced either by the direct combination of sulphuric acid with the proper oxide, or by its action on the metals. The latter has been already particularly described in the section on Sulphuric acid. They are also sometimes formed in nature by the action of the air on sulphurets. In this action the metal is converted into oxide, and the sulphur into acid, which together form the sulphate. Green vitriol is sometimes thus formed in soils from sulphuret of iron or *fool's gold*.

*What is gyp-
sum?*

770. SULPHATE OF LIME.—GYPSUM.—This is a white, soft mineral occurring abundantly in nature. The finer kinds are known as *alabaster*. Finely ground, it is employed extensively as a fertilizer of the soil under the name of *plaster*. Plaster of Paris is produced by heating gypsum until its water is expelled. The plaster, when pulverized, has the property of *setting* with water, or, in other words, forming a hard coherent mass.

*How are plas-
ter casts pro-
duced?*

771. PLASTER CASTS.—Plaster casts are made by reducing burned or powdered gypsum to the consistence of cream, with

water, and then pouring it into moulds. A coin may be copied by pouring such a paste into a small paper box containing the coin. Two parts of ordinary ground gypsum, heated moderately until vapor ceases to escape, and then mixed with one part of water, form a good proportion. The heat should not be carried very far beyond that of boiling water, or the plaster refuses to set.

Why do plaster casts harden? 772. The hardening of the plaster part takes place very rapidly. It is owing to the re-combination of the material with water. The water thus absorbed exists in a solid form in the compound, as in other salts.

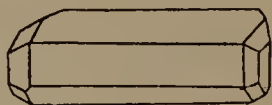
What is aluminated plaster? 773. ALUMINATED PLASTER.—Harder and better casts, more nearly resembling marble, are made by steeping the burned gypsum for six hours in strong alum water, and then reheating it at a higher temperature. After being again pulverized, it may be used like ordinary plaster, but requires more time to harden.

Describe sulphate of soda, and its preparation. 774. SULPHATE OF SODA.—GLAUBER'S SALT.—This is a white salt forming crystals belonging to the third system, such as

are represented in the figure.

It is used to some extent in medicine, and in large quantities for the pro-

duction of carbonate of soda. It is prepared by pouring oil of vitriol upon common salt. A double decomposition takes place between the salt and the water of the acid; hydrochloric acid is formed, which passes off, and soda, which remains combined with the sulphuric



acid. It is to be understood that this reaction between water and common salt, takes place only when sulphuric acid is present. The method of making the experiment is given in the paragraph on the preparation of hydrochloric acid.

What is said of its crystals? 775. Sulphate of soda may be obtained in crystals by evaporation. These crystals, like those of many other salts, lose their combined water on exposure to the air and become converted into a white powder. This change is called *efflorescence*, and the salt which experiences it is called *efflorescent*. In preparing the salt on a large scale, for conversion into carbonate of soda, great quantities of hydrochloric or muriatic acid are incidentally produced.

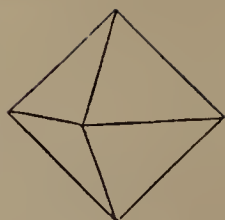
What is sulphate of baryta? How prepared? Uses?

776. SULPHATE OF BARYTA.—The sulphate of baryta is a white insoluble substance, which may be obtained as a precipitate, by double decomposition of any soluble baryta salt with a soluble sulphate. It is a mineral of frequent occurrence, known as *heavy spar*, much used for the adulteration of white lead, in which it may be easily detected as a residue, on dissolving the white lead in dilute nitric acid. The sulphate of lead is another of the few insoluble sulphates.

Describe alum, and its preparation.

777. ALUM.—Ordinary alum is a double sulphate of alumina and potassa. Solutions of the two salts, when mixed, combine to form the double salt. The sulphate of alumina required in the process may be obtained by dissolving alumina from common clay by sulphuric acid.

Or it may be produced by exposing certain clays or slates which contain sulphuret of iron to the action of the air. Under these circumstances the sulphur becomes converted into sulphuric acid, which unites with both oxide of iron and alumina. From this mixture the protosulphate of iron is separated by crystallization, leaving a solution of sulphate of alumina to be used in the preparation of alum.



What is burnt alum? 778. On heating alum in a crucible or pipe-bowl, it swells up into a light porous mass and is converted into *burnt alum*. At the same time it loses its water of crystallization, of which it contains twenty-four molecules to each molecule of the double sulphate.



What is said of other alums?

779. OTHER ALUMS.—The name alum is applied to a number of salts of analogous composition to the common alum already described. In one of these, sesquioxide of chromium, and in another, sesquioxide of iron, takes the place of the alumina or sesquioxide of alumina. In a third kind of alum oxide of ammonium replaces the potassa. All of these alums contain the same number of molecules of water of crystallization. They have all the same crystalline form, and, if mixed in solution will crystallize together. They are, therefore, isomorphous salts. Their perfect analogy of composition will be best seen by the inspection of their formulæ, given in the Appendix.

What is said of vitriols?

780. OTHER SULPHATES.—VITRIOLS.—Several of the sulphates have received the

common name of *vitriols*. Sulphates of zinc, copper, and iron are called respectively white, blue, and green vitriol. Green vitriol readily absorbs oxygen from the air, and becomes brown, from the accumulation of peroxide of iron upon its surface. A solution of it is changed to a yellowish-red color by the oxidizing action of either nitric acid or chlorine. A crystal of blue vitriol is represented in the figure. The form belongs to the fifth system.



NITRATES.

How are nitrates formed?

781. The nitrates are formed by the action of nitric acid on metals, as already explained, and also by the action of the acid on oxides previously formed. In the latter case, the metallic oxide takes the place of the water of hydration which always belongs to the acid. They are also produced by double decomposition. This latter method is illustrated below, in the preparation of nitrate of potassa from the nitrate of lime. The figure represents a crystal of saltpetre. The form belongs to the third system.



How is nitrate of lime produced?

782. NITRATE OF LIME.—This salt is of considerable interest, from the fact that it is employed in the production of saltpetre or nitre. It is formed in the so called, *nitre beds*, by mixing together refuse animal matter with earth and lime. In the gradual putrefaction of the animal matter which follows, its nitrogen takes oxygen from the

air, and is converted into nitric acid. The acid then combines with the lime to form the nitrate. The salt is afterward extracted by water. The formation of nitric acid, above mentioned, takes place only in the presence of alkaline substances. In their absence the nitrogen passes off, combined with hydrogen, as ammonia. Even in the presence of lime, there is reason to believe that ammonia is first formed, and its constituents afterwards converted into nitric acid and water.

Explain the formation of nitre.

783. NITRATE OF POTASSA.—NITRE, OR SALTPETRE.—This salt is a constituent of certain soils, especially in warm climates.

These soils always contain lime, and are said to be never entirely destitute of vegetable or animal matter. It is obvious, therefore, that nitrate of potassa may be formed in them, as the same salt of lime is formed in the nitre beds just described. A small proportion of nitric acid exists in the atmosphere, combined with ammonia. This, also, may be a source of part of the nitric acid of the nitrous soils. Again, it is probable that nitric acid is slowly formed from the atmosphere by the direct combination of its elements in the porous soil. Nitre, on being highly heated, yields a third of its oxygen in the form of gas.

How is nitre obtained from nitrous soils?

784. Nitre is obtained from nitrous soils by lixiviation with water and subsequent crystallization. From nitrate of lime, it is produced by double decomposition with carbonate of potassa. Carbonate of lime precipitates, while nitrate of potassa remains in solution. This may be afterward poured off, evaporated, and crystallized.

Mention some of the uses of nitre.

785. USES OF NITRE.—Nitre is extensively employed by the chemist and in the arts, as an oxidizing agent. A few grains of it introduced into a solution of green vitriol or sulphate of iron, to which some free sulphuric acid has been added, will immediately change its color. The sulphuric acid sets nitric acid at liberty, to which the oxidation and change of color are to be attributed. Nitre, when heated, yields part of its oxygen, as before stated. If heated with metals, it converts them into oxides. The principal use of nitre is in the manufacture of gun-powder.

How are nitrate of ammonia and laughing gas produced?

786. NITRATE OF AMMONIA.—LAUGHING GAS.—Nitrate of ammonia may be prepared from the carbonate by evaporation with nitric acid. When heated, the hydrogen of the ammonia and an equivalent quantity of the oxygen of the nitric acid unite to form water, and the residue of both passes off as protoxide of nitrogen or nitrous oxide. The compound is also called *laughing gas*, from the exhilarating effects which it occasions when breathed in considerable quantity. Impurity of material or excess of heat occasion the production of an impure and deleterious gas. In view of these facts, the preparation and inhalation of laughing gas is not to be recommended to the student.

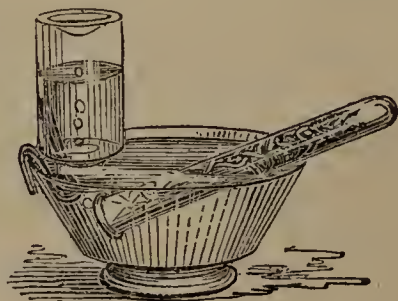
Explain the action of the different constituents of gun-powder.

787. GUN-POWDER.—Gun-powder is a mixture of nitre, charcoal, and sulphur. When ignited, the carbon burns instantaneously, by help of the oxygen of the nitre, thus producing a large volume of carbonic acid gas. To

this gas, together with the nitrogen which is also set at liberty at the same moment, the force of the explosion is due. The sulphur at the same time combines with the potassium of the nitre, and remains with it as a sulphuret of potassium. Three equivalents of carbon to one of nitre and one of sulphur expresses very nearly the composition of gun-powder. It varies, however, according to the uses for which it is intended and the country in which it is manufactured. From the proportion, by equivalents, the relative weight of the constituents can readily be calculated.

*How are the
gases col-
lected?*

788. COLLECTION OF THE GASES.—For the production and collection of the gases evolved in the combustion of gun-powder, the fuses of ordinary “*fire crackers*” may be employed. Several of them are to be ignited at the same time in an ordinary test-tube. The mouth of the latter being then brought under a filled and inverted vial, the gases are collected as fast as they are evolved.



*Describe ni-
trate of silver.
What are its
uses?*

789. NITRATE OF SILVER.—Nitrate of silver or *lunar caustic* is employed in surgery, for cauterizing wounds. A solution of the salt in which the oxide has been precipitated by ammonia and re-dissolved by a slight excess, is extensively employed as an indelible ink. The black color comes from oxide of silver and finely divided metal precipitated in the cloth. It may be removed by soaking in solution of common

salt, and thus converting the silver of the mark into chloride of silver. This is soluble in ammonia, and may be afterward extracted by that agent. Nitrate of silver is also the basis of most dyes for the hair.

Describe the other nitrates. 790. OTHER NITRATES.—Nitrate of soda is a white salt, found native in South America. It is used in the manufacture of nitric acid, and, to some extent, as a fertilizer of the soil. The remaining nitrates are soluble salts, of colors corresponding to the solutions of the metals, as already described. The uses of the nitrates of silver and bismuth have already been mentioned.

CARBONATES.

Describe the carbonates. 791. CARBONATES.—The carbonates are, for the most part, white or light colored salts, of which chalk may serve as an example. The carbonate of copper is found native, both as blue and green malachite. All of the carbonates, excepting those of the alkalies, may be decomposed by heat. The latter are soluble and retain their acid at the highest temperatures. The figure represents a crystal of carbonate of lime or *calc spar*.



How are the insoluble carbonates prepared? 792. PREPARATION.—The insoluble carbonates may be produced by precipitating solutions of the metals or their salts by carbonic acid or solutions of the alkaline carbonates. In the latter case, a double decomposition occurs with exchange of acids and bases.

*What is said
of carbonate
of potassa?*

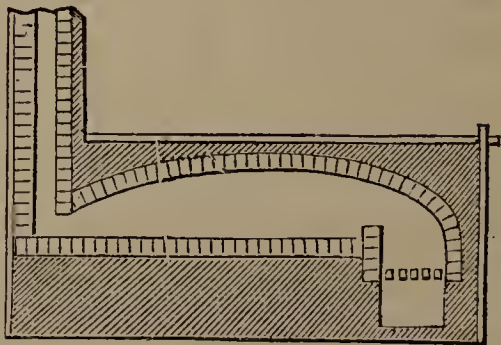
793. CARBONATE OF POTASSA.—POTASH. The method of preparing potash and pearlash, from wood ashes, has already been considered in the paragraph on Potassa. *Saleratus* is a carbonate containing a large proportion of carbonic acid. Its use for “raising” bread and cake is familiar. The acid employed with it, sets the carbonic acid gas at liberty and thus puffs up the “sponge.”

*Describe car-
bonate of
soda.*

794. CARBONATE OF SODA.—SODA.—Carbonate of soda is commonly known under the name of *soda*. It is a white soluble salt, familiar from its use in Seidlitz and soda powders. Its carbonic acid is the source of the effervescence in these preparations.

*How is carbo-
nate of soda
prepared?*

795. Carbonate of soda is prepared from the sulphate of soda. This salt being heated with charcoal is converted into sulphide of sodium. On heating the latter with carbonate of lime, a double decomposition occurs, and carbonate of soda is produced, with sulphide of calcium as an incidental product. Both parts of the process are combined in practice. Sulphate of soda, chalk, and coal, are heated together in a reverberatory furnace, the carbonate of soda is then dissolved out from the fused mass, dried, purified, and subsequently crystallized. The sulphide of calcium would dissolve at the same time, and thus defeat the process, were it not rendered insoluble by combination with a certain quantity of lime.



Describe another method.

796. Another method of manufacturing carbonate of soda, consists, essentially, in separating sulphur from the sulphate, by means of oxide of iron, and substituting carbon in its place. In this process also, the materials are heated with charcoal, in a reverberatory furnace, and the carbonate afterward extracted by water. The impure uncrystallized carbonate of soda, is known in commerce, as *soda ash*, and is largely employed in the manufacture of hard soap and in other processes.

What is sal volatile?

797. CARBONATE OF AMMONIA.—SAL VOLATILE.—The ordinary *sal volatile* of the shops, used as smelling salts, is a carbonate containing three equivalents of acid to two of base. It wastes away gradually in the air, and passes off in a gaseous form.

How is sal volatile prepared?

798. PREPARATION.—Sal volatile is prepared by heating together carbonate of lime and chloride of ammonium. Carbonate of ammonia immediately passes off, while chloride of calcium remains behind. The carbonate is led into a cold pipe or chamber, where it takes the solid form. The mixture of chalk and sal ammoniac is sometimes used as smelling salts. The production of sal volatile from the mixture is very gradual if heat is not applied.

How is it proved to be volatile?

799. The property from which the salt receives its name, may be illustrated, by holding in its vicinity a rod or roll of paper moistened with strong muriatic acid. A dense cloud of sal ammoniac is immediately produced in the air, from the union of the two vapors. The



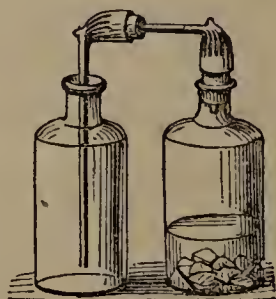
experiment is more striking, if the sal volatile is warmed in a cup or other vessel. This salt is sometimes used by bakers for making bread and cakes light and spongy.

*What is said
of carbonate
of lime?*

800. CARBONATE OF LIME.—Carbonate of lime, in the form of chalk, marble, and ordinary limestone, is a most abundant mineral. Whole mountain chains consist of the latter rock. The shells of shell-fish are principally carbonate of lime. There is good reason, indeed, to believe that all limestones have their origin in accumulations of such shells, which have been consolidated in the course of ages.

*How is the
solubility of
carbonate of
lime in car-
bonic acid
shown?*

801. SOLUBILITY IN CARBONIC ACID.—The solubility of carbonate of lime in carbonic acid is readily shown, by passing a current of the gas through water clouded with pulverized chalk or marble. Other mineral substances which form the food of plants are dissolved by the same means, and then find their way into the roots, to subserve the purposes of vegetable life.



*What is said
of incrusta-
tions in boil-
ers?*

802. INCRUSTATIONS IN BOILERS.—Carbonate of lime dissolved in carbonated water is again precipitated on boiling the solution. This is owing to the escape of the acid. Incrustations in tea-kettles and steam-boilers, in limestone districts, owe their origin to the same cause. In some cases, the crust is formed of gypsum or other earthy matters contained in the water. One method of avoiding this inconvenience in steam-boilers, is by

the addition of a smaller boiler in which the water is first heated and its sediment deposited.

*What are
stalactites?*

803. **STALACTITES.**—The masses of carbonate of lime which hang like mineral icicles from the roofs of caverns are called *stalactites*. The water that penetrates the soil is the architect of these curious forms. Impregnated with carbonic acid derived from decaying vegetation, it takes up its load of carbonate of lime as it settles through the rock, and deposits it again on exposure to the air of the cavern, in various and often fantastic shapes. Another portion of water, dripping to the floor of the cavern, builds up similar forms, called *stalagmites*, from below.

*How is artifi-
cial marble
produced?*

804. **ARTIFICIAL MARBLE.**—The surface of wood or stone may be marbled by covering it with successive coats of milk of lime, and allowing each in turn to dry before the next is applied. The surface is then smoothed and polished, and carbonic acid finally applied by which it is converted into marble. The milk of lime is simply a mixture of slaked lime and water, and may be so colored as to produce a variegated surface.

PHOSPHATES

*Describe the
phosphates.*

805. **PHOSPHATES.**—The phosphates, with the exception of those of the alkalis, are, for the most part, white insoluble salts. Phosphate of lime may be taken as an example. The white residue which is obtained on heating the bones of animals until all the animal matter is destroyed and expelled, is principally phosphate of lime.



Why is ordinary phosphoric acid termed tribasic?

806. Ordinary phosphoric acid has the property of combining with and neutralizing three equivalents of base, instead of one, as is the case with most other acids. It is therefore called a *tribasic* acid. The hydrated acid contains, also, three equivalents of water, and may be regarded as a salt in which the water acts the part of base. Arsenic acid is similar in this respect, as well as in the amount of oxygen which it contains and in the salts which it forms with bases. Two other kinds of phosphoric acid may be prepared from that above mentioned; the first combines with one, and the second with two equivalents of base.

How are the phosphates prepared?

807. PREPARATION.—The phosphates of the alkalies may be produced by the action of phosphoric acid on the proper carbonates. The remaining phosphates may be precipitated by solution of phosphate of soda from solutions of the metals or their salts. As in other cases of precipitation, there is here a double decomposition with exchange of acids and bases.

Describe the preparation of superphosphate of lime.

808. SUPERPHOSPHATE OF LIME.—A mixture bearing this name, formed by the action of dilute sulphuric acid on burned bones, is extensively used as a fertilizer of the soil. The sulphuric acid, when added, appropriates part of the lime of the bones, forming with it gypsum; at the same time, it leaves the phosphoric acid which it displaces free to combine with another portion of phosphate of lime and thereby to render it soluble. The commercial article is a mixture of this

soluble substance with the gypsum and animal charcoal produced in its formation. Other materials are often added, increasing or diminishing, according to their nature, its agricultural value. The basis of the manufacture is commonly the refuse bone black of sugar refineries.

What is said of other phosphates? 809. OTHER PHOSPHATES.—The phosphate of soda is used in medicine and by the chemist, to produce other phosphates. The phosphate of silver is a beautiful yellow precipitate, obtained by precipitating salts of silver with phosphate of soda or any other salt containing phosphoric acid.



SILICATES

What is said of silicates? 810. The silicates form an exceedingly large class of salts. They are, for the most part, insoluble, and are variously colored. *Mica* and *feldspar*, two of the constituents of granite, may serve as examples. As components of this and other rocks, the silicates make up a very considerable portion of the mass of the earth.



How are silicates prepared? 811. PREPARATION.—Most silicates may be artificially formed by fusing together quartz sand and the proper oxide. This is done in the manufacture of glass, to be hereafter described. Silicates may also be formed by precipitating solutions of metals or their salts by the solution of an alkaline silicate.

What is the composition of clay? 812. CLAY.—Clay is a silicate of alumina, commonly containing silicate of potassa and other materials in small proportion. The best *kaolin* or porcelain clay is perfectly white, and is nearly pure silicate of alumina.

How is soluble glass made? 813. SOLUBLE GLASS.—Soluble glass is made by fusing sand with potassa or soda. Its production may be illustrated in a soda bead, by subsequently re-fusing it with addition of sand. As the silicic acid combines with the soda carbonic acid is expelled, as will be evident from an effervescence on the surface of the bead. Soluble glass is sometimes used as a sort of varnish for rendering wood fire proof.

Describe the manufacture of window glass. 814. WINDOW GLASS.—Common window glass is a silicate of lime and soda. To form it, chalk, soda, quartz sand and old glass are fused together until the mass becomes fluid. The molten glass is then blown, by means of an iron tube, as soap bubbles are blown with a pipe. The first form of the bubble is that represented in the figure. The glass blower next contrives to lengthen out the bubble, as he blows it, to a larger size, and finally to blow out the end by a strong blast from his lungs. It is then trimmed with a pair of shears, and the other end cracked off by winding round it a thread of red hot glass. Such a thread is readily produced by dipping an iron rod into the pot of molten glass, and then withdrawing it. The bubble of glass is thus



brought to the form of a cylinder, such as is represented in the figure. The cylinder is then cracked longitudinally, by letting a drop of water run down its length, and following it by a hot iron. It is subsequently reheated, opened, and flattened out into a sheet, which is then cut into panes of smaller size, if required.



*How are glass
tubes made?*

815. GLASS TUBES.—To make a glass tube, a bulb is first blown, such as is represented on the previous page. An assistant then attaches his tube to the hot bulb at the opposite side, and moves backward. The glass is thus drawn out as if it were wax, and the cavity within it is elongated to a smooth and perfect bore.

Glass bottles?

816. GLASS BOTTLES.—Bottles and a great variety of other objects of glass are made by the enlargement of similar bulbs within a mould of the required shape. Bottle glass is usually made of cheaper and less pure materials than window glass, and contains, in addition to the materials before mentioned, alumina and oxides of iron and manganese. It owes its green color to the protoxide of iron.

Glass mirrors?

817. GLASS MIRRORS.—Plate glass, such as is used for mirrors, instead of being blown, is cast in metallic tables of the required shape, and then rolled out and polished.

What is crystal glass?

818. CRYSTAL GLASS.—This name is given to a highly brilliant glass containing potassa and litharge as bases. It is used for prisms, lenses, lustres, and the finer qualities of cut glass ware.

With the addition of borax, it is also employed for imitations of precious stones.

What is enamel?

819. ENAMEL.—Enamel is an opaque glass, produced by the addition of some material which does not dissolve in the fused mass. Binoxide of tin is the material commonly employed. Various tints may be imparted to enamel, as to ordinary glass, by the addition of small quantities of metallic oxides. A thin surface of enamel is often baked on to a metallic surface, as in the case of watch dials and various objects of jewelry.

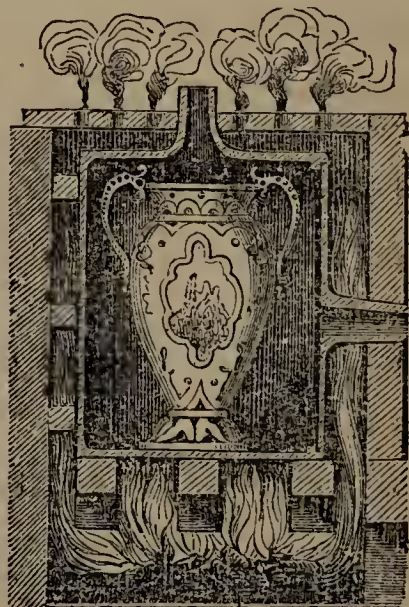
How is glass colored?

820. COLORED GLASS.—Glass is colored and stained by the addition of various metallic oxides. The peculiar coloring effects of these substances have already been mentioned, in the section on Oxides.

EARTHENWARE.

*What is the basis of all earthenware?
How is porcelain made?*

821. Clay is the basis of all earthenware, from the finest porcelain to the coarsest brick. Being first fashioned by moulds or other means into the proper form, it is dried, baked, and subsequently glazed to render it impervious to water. In the manufacture of porcelain glazing is not essential. Sand and chalk are added to the original material, and the heat is carried so high as to bring the whole mass into a semi-vitreous condition. This is also the case in certain kinds of stone-



ware. Porcelain is, however, commonly glazed to add to its beauty.

*Describe the
process of
glazing.*

822. GLAZING.—Earthenware after its first baking is porous, and therefore unfit for most uses for which it is intended. It is subsequently covered with a thin paste formed of the constituents of glass. Being then subjected a second time to the heat of the furnace, a thin glass or *glaze* is formed upon the surface. The glazing of certain wares is effected by exposure at a high temperature to vapors of common salt. A double decomposition ensues with the oxide of iron which the ware contains, by which soda is formed. This immediately fuses with the silica and other materials to form the glaze. The chloride of iron which is formed at the same time passes off as vapor. A paste of pounded feldspar and quartz, to which borax is sometimes added, is employed in glazing porcelain.

*What is said
of porcelain
painting?*

823. PORCELAIN PAINTING.—Metallic oxides form the basis of the pigments used in painting upon porcelain. The coloring effect of the different pigments is mentioned in the chapter on metallic oxides. The patterns on ordinary earthenware are first printed on paper, and then transferred, by pressure, to the unglazed ware. The paper is afterwards removed by a wet sponge.

BORATES.

*What is
borax?*

824. BORAX.—Borax is the only important salt among the compounds of boracic

acid. The salt contains two atoms of acid to one of base, and is therefore a biborate. It is a white soluble salt, which swells up when heated, in consequence of the escape of its water of crystallization.



How is borax prepared? 825. PREPARATION.—Borax is found in solution in the water of certain shallow lakes in India. It remains as an incrustation in the beds of these lakes when they dry up in summer. It is also prepared by the action of a solution of boracic acid on carbonate of soda.

What is said of borax glass? 826. BORAX GLASS.—The light spongy mass which is produced on heating borax, may be melted down by greater heat and converted into borax glass. This glass has the property of dissolving metallic oxides, and receiving from them peculiar colors, as described in a former paragraph. The chemist often determines the metal which a salt or oxide contains, by the color which it thus imparts to glass. The method of making the experiment has already been given.

Why is borax employed in soldering? 827. SOLDERING, WELDING, ETC.—Borax is employed in soldering metals, to keep the metallic surfaces clean. It does this by dissolving the coating of oxide which forms upon them, and forming with it a glass which is fluid at a high temperature, and easily pushed aside by the melted solder. Its use in welding iron depends on the same property. Borax is also used, to some extent, in medicine. It is also a constituent of the glass called

jewellers paste, which is used in producing imitations of precious stones.

CHROMATES.

*How is chrome
yellow pre-
pared?*

828. CHROME YELLOW.—To prepare this pigment, a solution of the commercial bichromate of potassa is added to a solution of sugar of lead. A double decomposition ensues; the result of which is the production of a beautiful yellow precipitate, known as *chrome yellow*. The precipitate is a chromate of lead. The bichromate of potassa used in the experiment, is made from the mineral chrome iron, which has been mentioned in a previous chapter. The acid itself, which is without practical applications, may be made from the salt. It contains, like sulphuric acid, three atoms of oxygen.



*How is chrome
yellow con-
verted into
chrome
orange?*

829. CHROME ORANGE.—Chrome yellow may be converted into *chrome orange*, by digestion with carbonate of potassa. Cloth dyed yellow by dipping it alternately into a solution of bichromate of potassa and sugar of lead, is instantaneously changed to orange by immersion in boiling milk of lime. This action of the lime, as well as that of carbonate of potassa, depends upon its abstracting a certain portion of the chromic acid, leaving thereby a chromate of lead of different composition and color.

Describe the preparation of oxide of chromium.

830. CHROME GREEN.—On adding sulphuric acid and a few drops of alcohol to a solution of bichromate of potassa, the solution is immediately changed from red to green. The alcohol has taken oxygen from the chromic acid, and converted it into oxide, which remains in solution, as a soluble sulphate. Part of the sulphuric acid has at the same time combined with the potassa, to form sulphate of potassa. It is to the presence of the sulphate of chromium in solution that the color of the liquid is due. By adding an alkali to the solution, a green precipitate of the hydrated oxide is produced. This oxide forms a kind of “chrome green.” App. 830.

MANGANATES.

What is chameleon mineral?

831. CHAMELEON MINERAL.—By fusion with nitre, the black oxide of manganese may be still further oxidized, and converted into an acid. The new acid at the same time combines with the potassa of the nitre to form manganate of potassa. This salt has been called *chameleon mineral*, from the spontaneous change of color which takes place in its solutions.

How is chameleon mineral prepared?

832. PREPARATION.—The experiment may be made by filling a pipe stem with a mixture of the materials, and thrusting it into burning coals. It may be made on a still smaller scale before the blow-pipe, using a broken pipe-bowl to support the materials. The compound dissolves in water, forming a green solution, which on standing is gradually changed to a beautiful red.

Explain the action of sulphuric acid upon it.

833. EXPLANATION.—The addition of a few drops of sulphuric acid, produces the above-mentioned change instantaneously.

This acid combines with the potassa, setting the manganic acid at liberty. One portion of manganic acid then appropriates part of the oxygen of the other part, and converts itself into hypermanganic acid, which still remains combined with potassa, imparting the red color to the solution. The deoxydized portion of the acid precipitates, at the same time, as bin-per oxide. The remaining manganates are not of especial interest or importance.

THE DAGUERRETYPE.

Explain the daguerreotype briefly.

834. THE DAGUERRETYPE.—The daguerreotype may be regarded as a painting in mercury, upon a silver surface. The employment of mercury is preceded by what may be called an invisible painting upon the silver. This is accomplished, like the production of an image in a mirror, by mere presentation of the picture, or other object to be copied, before the prepared plate. The mercury, afterward used in the form of vapor, adheres to the plate, and forms its white amalgam, just in proportion to the lights and shades of the previous image thrown upon the plate.

Describe the process of taking daguerreotypes.

835. THE DAGUERREOTYPE PROCESS.—In order to prepare the plate for what has above been called the invisible painting, it is exposed to vapors of iodine, and thereby covered

with a coating of iodide of silver.* A picture or face to be copied being presented before the prepared plate, the light which proceeds from it acts chemically upon the iodide of silver. It decomposes it, to a certain extent, and separates the iodine, thus opening the way for the mercurial vapor which is afterward to be employed. The light has this effect just in proportion to its intensity. That which proceeds from the lighter portions of the face, or dress, has most effect; that from the black portions, none at all, and that from the intermediate shades, an effect in exact proportion to their brightness. When the plate is afterward exposed to the action of the mercurial vapors, they find their way to the silver surface and paint it white, just in proportion as this chemical effect upon the iodine has been produced, and the way has been opened for their admission. The darker portions of the plate are pure silver. They appear dark in contrast with the white amalgam.†

836. USE OF THE LENS.—In taking daguerreotypes, a lens is placed between the object to be copied and the plate, in order that an image may be formed on the silver surface. Such an image is analogous to that formed on the retina of the eye. The image is commonly made smaller than the object. Where this is the case, the rays are used in a concentrated condition, and their effect is proportionally increased.

* Bromide and chloride of iodine are employed to give additional sensitiveness to the plate. The iodide is thus made to contain a portion of bromide and chloride of silver.

† The art of taking portraits from the life by the Daguerreotype process, was invented by Dr. J. W. Draper, of the N. Y. University.

*What is said
of the chemi-
cal action of
light? What
rays possess
this power?*

837. CHEMICAL ACTION OF LIGHT.—The chemical action of light, on which the production of daguerreotypes depends, is one of the most interesting and remarkable of chemical phenomena. The rays of the sun are so subtle that they pass through solid crystal and leave no trace of their passage. Yet with them comes a power that can overcome the strongest chemical affinities, and resolve the compounds which it has produced into their original elements. This power resides in what are called the *chemical*, *actinic*, or *tithonic* rays. These are mingled, under ordinary circumstances, with those of light, but are capable of separation by certain media.

*What are pho-
tographs?*

838. PHOTOGRAPHS.—Pictures produced through the agency of light, whether upon silver or paper, are, properly, photographs or *light pictures*; the name, however, is especially appropriated to the latter. For the purpose of illustration, a method of producing *negative* pictures, as they are called, will be here given.

*How is sensi-
tive paper
prepared?*

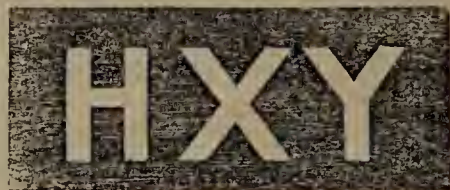
839. The sensitive paper required in the process, is prepared by floating a slip of letter-paper for two or three minutes upon salt water; and then for double the time, with the same side down, on a solution of nitrate of silver. Chloride of silver forms within the fibres, and renders the paper sensitive to light. After each immersion, the slip should be dried off by blotting paper. When finished, it should be immediately laid away between the leaves of a book, for protection against the light.

*What effect
has direct sun-
light upon
sensitive pa-
per?*

840. Such paper, if placed in direct sun light, becomes violet and then dark brown in the course of a few minutes. The change is owing to the partial decomposition of the chloride of silver. A new substance, of darker color, is then produced; whether a lower chloride of different shade, or a mixture of metal and chloride, or a compound of oxide and chloride, is not very certainly known.

*How may cop-
ies be pro-
duced by
means of sen-
sitive paper?*

841. If a cross or other device cut from dark paper is pressed down upon sensitive paper, by means of a glass plate, and be left to cover it during the exposure to light, the paper will be protected beneath it, and an exact copy of the device thus obtained. The most delicate lace may be copied by the same method. In reproducing engravings by this means, they must be previously rendered translucent, so that the unprinted portions will allow the light to pass. This may be accomplished by waxing them, with the help of a hot iron, or by simple oiling. The dark parts of the engraving appear light, and the light portions dark, in the picture. By copying the copy, a true representation of the original device, called a "positive picture," is obtained. Both the "positive" and "negative" are soon destroyed by the action of light upon the whole sensitive surface. But the means exist for rendering them entirely permanent in any exposure



How is the silver solution prepared?

842. THE SILVER SOLUTIONS.—To prepare the silver solution, above required, put a three cent piece into a test-tube, having a diameter a little larger than the coin itself. Then fill the tube to the depth of an inch with a mixture of equal parts of nitric acid and water. The solution of the coin commences immediately. When it is completed, fill up the tube with water, mix well by shaking, and the solution is ready for use. For the same quantity of salt solution, enough common salt to fill about two-thirds of an inch of the tube may be used.

Describe briefly the process of anastatic printing?

843. ANASTATIC PRINTING.—This name is given to a process by which any kind of printed matter may itself be converted into a plate from which new copies may be printed. It consists, essentially, in the transfer of the letters or other design, to zinc, by pressure, the paper having been previously moistened by dilute acid. The oil of the ink remains; and the paper is removed. The zinc plate is then used like an ordinary lithographic stone. When the inked roller is passed over it, the ink only adheres to the design, from which an impression may then be taken by the ordinary process.

What is said of counterfeiting by the above process?

844. COUNTERFEITING.—Bank notes may be counterfeited by either of the above processes. Great apprehension has been felt lest they should render the use of paper money entirely insecure. An effectual means of protection against such counterfeiting has recently been devised.*

* Seropyan's patent.

Copying by the anastatic process, obviously depends upon the absence of oil from the back ground of the picture. The employment of an oil tint, instead of blank paper, for the back ground, is therefore a perfect security against it. Counterfeiting by the photographic process depends on the fact that the light which falls on a picture is intercepted by the dark letters. If they are printed in a transparent blue, the chemical rays are permitted to pass through the printed as well as the unprinted portions. A copy with the contrasts of the original picture is thereby rendered impossible. By printing with blue ink, on a back ground of some other color, both of the securities against counterfeiting above mentioned are combined.

CHEMICAL ANALYSIS.

Describe analysis by solvents.

845. DIRECT METHOD.—In the process of analysis, advantage is taken of the distinguishing properties of different substances to effect their detection and separation. They may sometimes be separated by the employment of a solvent which acts upon one and leaves the other undissolved. The separation of silver from gold in the process of assaying is a case in point.

Describe direct analysis by precipitation.

846. A more common method is to bring the whole substance into solution, and afterward separately to precipitate its several constituents by agents which have no effect upon the rest. The separation of alumina from lime may serve as an example. A mixture of the two being dis-

solved in acid, the former may be precipitated by ammonia. The latter remains in solution and may be afterward removed by some other agent.

Illustrate the indirect method. 847. INDIRECT METHODS.—Indirect methods of analysis are much more frequently employed than either of the above. The detection of silver in a copper alloy may serve as an example. The alloy being first dissolved, hydrochloric acid is added to the solution, as a test. The appearance of a white insoluble curd, is taken as conclusive evidence of the presence of silver. No other metal of an alloy ever combines with the chlorine of hydrochloric acid to form such a precipitate. The evidence is quite as satisfactory to the chemist as that which would be obtained by the separation of the silver in the metallic form.

How is the weight calculated? 848. Neither is separation necessary in order to ascertain the exact weight of the metal which has been precipitated. Advantage is here taken of the well-established law of combination by definite proportions. The chloride of silver produced in the experiment, is invariably of the same proportional composition. It is made up of an atom of silver to every atom of chlorine. Its weight being ascertained by the balance, the amount of silver which it contains may be calculated with absolute precision, by help of the table of atomic weights. This weight being compared with that of the original alloy, gives, by a simple calculation, the per centage proportion of silver which the alloy contains. The nature and quantity of other constituents, whether of compounds

or mixtures, is determined by processes analogous to those which have above been described.

How is separation into groups effected? 849. SEPARATION INTO GROUPS.—In the analysis of substances containing many constituents, a separation into groups precedes the isolation of the individual constituents.

This is effected by the use of certain agents in succession, which have the property of precipitating whole groups. These being again dissolved, are commonly subdivided into smaller groups by similar means. The detection and separation of the individual constituents is finally accomplished by means already indicated. Some general idea of the process of inorganic analysis may be obtained from the foregoing. Particulars upon this subject must be sought in works on analytical chemistry.

PART IV.—ORGANIC CHEMISTRY.

CHAPTER I.—GENERAL VIEWS.

Of what does organic chemistry treat? 850. DEFINITION.—Organic chemistry is that division of the science which treats of substances of animal or vegetable origin. Starch, wood, gums, and resins; the juices, coloring matters, and fragrant principles of plants; the blood and flesh of animals; all come under its consideration. The process of germination, in which the plant first comes to be a living thing; the processes of decay and putrefaction, in which it returns again to the earth and atmosphere, are also to be treated under this division of the subject. Most organic forms of matter experience peculiar changes, and are converted into new substances by chemical means. The products of such transformations belong also to organic chemistry.*

Illustrate the variety of organic matter. 851. VARIETY OF ORGANIC MATTER.—The variety of organic matter is almost without limit. Every color of every dye, every flavor of every sweet or bitter herb, every gum,

* Carbonic acid, water, bone ash, and some other substances, are exceptions to the above rule, and are commonly treated under the head of inorganic chemistry. Though often produced from animal and vegetable substances, they also exist, ready formed, in nature, or may be readily made from inorganic or mineral matter.

and every resin, is a distinct organic substance. In the animal body, also, there is scarcely less variety. The fluids which dissolve the food, the blood which distributes it throughout the body, the color which tints the skin and hair, and the milk which nourishes the young, are a few of the substances which it includes.

852. MATERIALS OF VEGETABLE GROWTH.

What are the materials of vegetable growth?

With the exception of the small proportion of mineral matter which is derived from the earth, the materials out of which all animal and vegetable matter is formed are but few in number. Carbonic acid, ammonia, and water, are all. These are partly obtained from the air, and partly from the earth. Carbon, hydrogen, oxygen, and nitrogen, are the four elements which enter into their composition.

853. CONVERSION OF THE MATERIALS.—

What is remarkable in the new properties which result?

A vital force slumbers within the seed, which in germination wakes to life. Calling to its aid the light and warmth of the sun, it weaves, as it were, out of the scanty materials which have been mentioned, all of the varied forms of vegetable matter. Among the materials, one is a tasteless solid; the rest are tasteless gases. Yet sweet, sour and bitter flavors result from their combination, with all the other boundless variety of the organic world.

854. SIMILARITY OF COMPOSITION.—

Give some instances of similarity of composition with different properties.

more remarkable than the limited number of elements, from which so great a variety of organic substances is formed, is the similarity of composition in many sub-

stances which are yet so widely different in their properties. Vinegar differs from alcohol, for example, in containing a little more oxygen and a little less hydrogen, while the proportion of carbon in each is the same. Ether, also, contains the same amount of carbon as the alcohol from which it is formed, with a little less hydrogen and oxygen. Yet these substances are all widely different in their properties.

Mention some substances which are different in properties but identical in composition.

855. IDENTITY OF COMPOSITION.—Most remarkable of all, and at first view incredible, is the fact that many organic substances which are as widely different in properties as any which have been named, are still precisely the same in their composition; not alone containing the same elements, but containing them in precisely the same proportion. The most careful chemical investigation finds no difference of composition in wood, gum, and starch. The sugar which sweet milk furnishes, and the acid which exists in the sour, contain identically the same proportions of the same constituents. The oils of turpentine, lemon and pepper, so different in their taste, contain an equal quantity of carbon and hydrogen, without the addition of any third substance to either to account for the difference. Chemical investigation has thus brought us to results as strange as the dream of the alchemist, who believed that lead might be converted into silver, and copper into gold. All such substances, possessing the same composition with different properties, are called *isomeric* bodies—a term signifying their similarity of composition.

How are the above facts accounted for? 856. ARRANGEMENT OF ATOMS.—At a loss for any other way of accounting for such difference of properties, we are compelled to believe that it is because of difference of atomic arrangement. We have seen, in the case of iodide of mercury, mentioned in a former chapter, that a mere touch which produces motion and re-arrangement of its atoms in smaller groups, at the same time changes the color of the compound from yellow to red. Now the molecule of lactic acid, although containing the same relative proportion of all of its constituents, is smaller than the molecule of sugar of milk. It contains six atoms of carbon, six of hydrogen, and six of oxygen. The molecule of sugar of milk contains twelve of each, and can therefore furnish material to make two of acid, as it does in the souring of milk. And we may suppose that the change from sweet to sour is owing to this subdivision of the molecules.

How is diversity of properties accounted for when there is no difference of composition or size? 857. There are other cases of identical composition, in which there is no difference whatever in the size of the molecule, or the number of atoms which enter into its composition. This is the case with the oils of turpentine, lemon, and pepper, and perhaps with wood, starch, and sugar. The molecules of each are composed, not alone of the same proportion of the elements which enter into its composition, but, as there is reason to believe, of the same number of atoms of each. We are therefore compelled to look for the difference which shall account for their peculiar property, in a different arrangement of atoms inside of the mole-

cules themselves. A more satisfactory idea of this subject can be obtained after reading what follows, on the subject of organic radicals.

Give an instance of substitution that does not affect properties.

858: SUBSTITUTION.—A still more remarkable evidence of the influence of arrangement or grouping of atoms, remains to be mentioned. The internal arrangement of a molecule remaining the same, it seems to matter little, in many cases, of what it is composed. Hydrogen may even be replaced by chlorine, a body as widely different from it as anything which nature affords. By this means, ordinary acetic acid is converted into chloracetic acid, a body remarkably analogous in its properties to the acid from which it is formed. From this, again, by withdrawing the chlorine and restoring the hydrogen, the original acetic acid is reproduced.

What is said of the doctrine of types and substitutions?

859 TYPES.—The last example will serve as an illustration of the doctrine of chemical types and substitution, which certain chemists have endeavored to extend to all organic bodies. It has been maintained that the properties of these bodies depend solely upon arrangement, without any regard to the nature of the elements combined. The fact is, that while there are many cases of such substitution without essential change of properties, it is always attended by more or less modification of the original substance. The properties of a compound are therefore to be regarded as depending neither upon the nature or arrangement of atoms alone, but upon both causes combined. The

type, is the group which remains permanent, while the individual atoms which compose it are changed.

Illustrate the subject of compound radicals.

860. COMPOUND RADICALS.—Many organic bodies, although compounds, comport themselves as if they were *elementary* substances. Some of these are, as it were, metals; forming oxides, chlorides, and salts, like the true metals, which have already been considered. Others correspond more nearly to the metalloids. Each being organic, and like a metalloid, the root of a whole series of compounds is called an *organic radical*. The term radical is sometimes applied, for similar reasons, to chlorine, bromine, and other elementary substances. As the organic substances above referred to are composed of different elements, they are called *compound radicals*.

Give an example of a compound radical.

861. ILLUSTRATION.—A molecule of ordinary ether is composed of four atoms of carbon, five of hydrogen, and one of oxygen. But the carbon and hydrogen atoms are grouped together, forming a compound radical called *ethyle*, with which the oxygen is then combined to form ether or oxide of ethyle. Alcohol, as illustrated in the figure, is the hydrated oxide of this radical. Al-



dehyde, a substance to be hereafter more particularly described, has the same composition as alcohol, with the exception that two atoms of hydrogen have been removed from the radical. Acetic acid is formed from aldehyde by the re-placement of the removed hydrogen by the same number of atoms of oxygen. Ethyle itself may be prepared indirectly from the oxide, as potassium

is obtained from potassa or oxide of potassium, although by a different process.

What were the grounds of belief in the existence of ethyle previous to its discovery?

862. It is but a few years since the method of producing ethyle was discovered, but chemists believed in its existence almost as confidently before, as now. They reasoned that ether, which possesses the properties of an oxide, must have its radical, as Sir Humphrey Davy reasoned that potassa, soda and lime, must each contain its metal.

What are homologous series?

863. HOMOLOGOUS SERIES.—Certain of these compound radicals sustain to each other a curious numerical relation. They form a series in arithmetical progression, differing from each other in composition, by a common difference. Two atoms of carbon with two of hydrogen forms the common difference of the series referred to. Methyl, the radical of wood spirit, begins the list with two atoms of carbon and three of hydrogen. Ethyle follows—its composition being expressed by the addition of the common difference to the last. Margaryl, a radical contained in certain fats, is the seventeenth member of the series. Each of these radicals has, like ethyle, its own oxide or ether, its hydrated oxide or alcohol; also its aldehyde and its acid. A series of radicals, ethers, alcohols, aldehydes and acids, each in arithmetical progression, is thus produced. Such series are called *homologous*.

How are the different members produced?

864. PRODUCTION.—There are many gaps in most of the series, but the law of their progression is so well established, that no

doubt can exist as to the probable production of the missing members. The most complete of the series is given in the Appendix. Several of its more simple members may be produced by the action of nitric acid upon those higher in the scale. The acid has the effect of burning out part of their carbon and hydrogen, and thus reducing the relative proportion of these constituents.

865. PROGRESSION OF PROPERTIES.—

*What is said
of the relation
in their pro-
perties?*

There is also a similar progression of properties in the series. The earlier members of the alcohol series are highly volatile liquids; the later are solids at ordinary temperatures. Each increase of the relative properties of carbon and hydrogen produces a substance which is more fixed. In other words, the boiling point is higher for each successive member. The difference for each is about 34° F. The density of the vapors increases by a similar law. It is thus possible to predict, with accuracy, the boiling point and density of vapor in members of the series which have not yet been discovered.

866. RADICALS NOT ISOLATED.—

*Have all or-
ganic radicals
been isolated?*

larger part of the organic radicals have not yet been isolated. They are only known in their compounds, and the belief in their existence rests on the reasoning which has been given in a previous paragraph. This is regarded by chemists as abundantly sufficient for giving them names and places among chemical compounds. It is still, however, to be borne in mind, that the reasoning is not of the nature of absolute demonstration.

Mention some instances of the substitution of radicals.

867. SUBSTITUTION COMPOUNDS.—It was stated, in a previous paragraph, that there are many cases of substitution of the elements for each other without material change of properties. Certain cases of substitution of organic radicals for the elements remain to be mentioned. Theoretically considered, they form, perhaps, the most important discoveries which have for years been made in organic chemistry. Ammonia, as the student is already informed, is a volatile base whose molecules consists of one atom of nitrogen and three atoms of hydrogen. For one of these atoms of hydrogen, a molecule of the radical ethyle may be substituted, without very materially affecting its properties. The new ammonia thus formed is, like the first, a volatile base resembling the first so nearly in odor that it must have been repeatedly mistaken for it when accidentally produced. It is, however, a liquid at ordinary temperatures. This body has received the name of *ethylamine*. *Methylamine* is another body of the same series, produced by the replacement of two of the atoms of ammonia by the radical ethyl. *Triethylamine* is a third. By a similar substitution of hydrogen in ammonia by the radical methyl, another series is produced. Other radicals yield other series.

Mention other cases of substitution.

868. OTHER SUBSTITUTIONS.—There are other bodies which result from the substitution of different radicals or the metal platinum for the different atoms of hydrogen. Substitutions may even exist in the substituting radicals. All of these bodies retain the type of ammonia, and all of

them have basic properties. Many of them are strikingly similar to ammonia in odor and other properties. These substitution compounds afford still further evidence of the influence of arrangement of atoms and molecules in determining the character of chemical compounds. Many of these bodies differ very widely in their composition, and are yet closely allied in their properties. The methods of producing the substitutions above mentioned, are not of interest to the general student. A general notion of substitutions may be obtained from the double decompositions with which the student is already familiar.

CHAPTER II.

VEGETABLE CHEMISTRY.

*What is said
of germination
and the chan-
ges which at-
tend it?*

869. GERMINATION.—Before the processes of transformation of the materials of the earth and atmosphere into the innumerable products of the vegetable world can commence, a rudimental plant must be developed from the seed. The seed itself contains the materials for its production. These are principally starch, and gluten,* or the other substances analogous to each, which are hereafter described. The first stage in the process is the absorption of moisture and oxygen from the air, and the consequent production of *diastase*.† This substance has the remarkable property of converting starch into sugar, and rendering soluble all of the remaining gluten of the seed. By the appropriation of these materials, which have been stored up for it in the seed, the germ is developed into a perfect plant. It lets down its root into the soil in search of



* Gluten is the stringy substance which remains on removing the starch from dough by long continued kneading. It is further described in a subsequent paragraph.

† Diastase is an oxydized gluten which is always produced from gluten in germination.

mineral food, and lifts its leaves into the atmosphere, from which it is to derive its principal nourishment. At this point the true vegetative process commences.

What is the office of leaves of plants? 870. VEGETABLE NUTRITION.—Every leaf is a net to catch the fertilizing constituents of the air and appropriate them to the uses of the plant. It drinks them in through its countless pores, while the root supplies the remaining material and sends it upward in the rising sap. All of these materials meet in the leaf, which is the laboratory in which their conversion into vegetable matter is to be accomplished. The light and heat of the sun co-operate with the vital forces of the plant in the transformation which succeeds.

What gas is evolved from plants? 871. Whatever proportion of carbonic acid and water may be employed as the raw material, it is obvious, by comparison of their composition with that of vegetable substances, as hereafter given, that the oxygen is furnished in larger quantity than is required. Water alone yields a sufficient supply of this element, and more than enough for most substances that are to be formed. As the process of transformation proceeds, this gas is therefore constantly thrown off into the air. It is the refuse of the manufacture. Inasmuch as the evolution takes place from the leaf and other green parts of the plant, it is reasonable to suppose that this is the point where the process of transformation is principally conducted. The gum, sugar, or other materials produced, are dissolved in the descending sap, and transformed into other products, in the course of their circulation.

How may the evolution of oxygen by leaves be proved by experiment?

872. The agency of the leaves of plants in absorbing and decomposing carbonic acid, may be illustrated by the simple means represented in the figure. A glass funnel being filled with leaves and slightly carbonated water, is exposed to the sun. Oxygen gas is gradually evolved from the absorption and decomposition of the carbonic acid, and collects in the tube of the funnel. The oxygen may be tested by the usual means. The inversion of the funnel without loss of its contents, is easily effected, by covering it with a saucer and turning it in a pail of water.



What transformations occur in plants?

873. For certain transformations of material in plants, the evidence is entirely conclusive. The sugar beet and turnip are sweetest in the earlier stages of their growth. Later in the year they become hard and fibrous. This change is undoubtedly owing to the conversion of the sugar contained in the sap into woody fibre. In the ripening of grain, the sweet and milky juice of the young plant is converted into starch. Both hay and grain which are harvested too late, are deteriorated by the conversion of a portion of their starch and sugar into wood. In the ripening of fruits a portion of their acid is converted into sugar, as is evident from their change of flavor.

How is the action of the roots illustrated by experiment?

874. OFFICE OF THE ROOT.—The agency of the roots in supplying the plant with its mineral food, may be illustrated by the apparatus represented in the figure. In preparation for the experiment, a glass fun-

nel is tightly covered with a piece of bladder, and then filled with a solution of sugar or salt. A tube is then fitted, air tight, to its extremity. A glass vial, from which the bottom has been removed, may be substituted for the funnel in this experiment. On placing the apparatus, thus arranged, in a vessel of water, the latter penetrates the animal membrane, and adds itself to the contents of the funnel. The flow of the water is called *endosmose*, and is made appreciable to the eye by the rise of liquid in the tube. An *exosmose*, or flow of a small portion of the contents of the funnel outward, takes place at the same time.



Explain the phenomenon of endosmose.

875. The phenomenon exhibited in the above experiment, is to be accounted for by the difference of capillary attraction in the bladder for the two liquids. The spongioles, with which the extremities of the roots are provided, being filled with solutions of gum and sugar, act similarly upon the liquids of the soil. The endosmotic action, above described, is not confined to the roots of plants, but occurs in all their organs, through the walls of the minute cells of which they are composed. In connection with the transpiration of water from the leaves, it is probably the principal cause of the circulation of the sap. The relation of the plant and soil is further considered in a subsequent chapter.

Mention some of the more important vegetable substances.

876. CONSTITUENTS OF PLANTS.—Among the more important of vegetable substances are wood, starch, sugar and gluten. Woody fibre forms the mass of the plant; starch

and gluten collect in the seed ; while sugar and gum exist principally in the sap and fruit, or exude from the bark.

WOOD.

Mention different forms of woody fibre—its composition.

877. WOODY FIBRE.—Woody fibre, of which the fibrous threads of cotton or flax may serve as an example, is composed of carbon, hydrogen and oxygen. Its molecule contains twelve atoms of carbon, to ten of hydrogen and ten of oxygen. It constitutes the solid mass of all vegetable organs, whether hard and firm, like the fibre of the oak ; soft, like the pulp of fruits ; or fibrous, like cotton and flax. In one or the other of its varieties it thus serves us for shelter, clothing and food. It forms in plants the cells in which the vegetable juices are contained, and the veins or pores through which they circulate ; and has thence received its name of *cellulose*. In wood, these cells are often lined or filled with a substance of similar composition, to which the name of *lignin* has been given.

How is it changed by heat ?

878. CHANGE BY HEAT—GAS, CHARCOAL, ETC.—Under the influence of a high temperature, without access of air, wood is converted into charcoal, water, gases, wood vinegar and tar. It is to be observed that this change is the simple result of a re-arrangement of the atoms of the wood itself, without the help of additional oxygen or other elements. It is a most remarkable instance of va-



riety as produced by varied arrangement. The new substances are, as it were, different patterns woven from the same colored threads. The gases, of which carbonic acid, light and heavy carburetted hydrogen are the principal, have been already described. Wood vinegar and wood tar form the subjects of subsequent paragraphs. An excess of carbon remains behind as charcoal. The process is called *dry distillation*. The decomposition may be illustrated with saw-dust, in a test tube, as previously described.

879. SIMILAR CHANGE IN NATURE—PEAT.

Mention a similar change in nature.

Peat is formed by the decay of vegetable matter under water. The green slime which forms, in the summer, upon stagnant water is composed of minute plants. These die, each season, and sink to the bottom, until, in the course of years or ages, vast accumulations of vegetable matter are the result. By their partial decay or putrefaction under water, they are converted into *peat*. The process is analogous to that of dry distillation and the products similar. Carbonic acid and carburetted hydrogen gases are evolved, while a solid residue of peat remains behind. It may be regarded as a half-formed charcoal. Peat contains, in addition to its carbon, a little hydrogen and a still smaller proportion of oxygen. The carbonic acid evolved in the above process often makes its way to the surface, at some neighboring locality, in the form of a mineral spring.

How is bituminous coal formed?

880. BITUMINOUS COAL.—The formation of bituminous and anthracite coal is a consequence of a similar decay of vast accu-

mulations of vegetable matter which have been buried in the earth during previous ages of its existence. As a consequence of pressure, the material takes a different form from that already described, and is found, after ages have elapsed, as bituminous coal.

How is anthracite formed? 881. ANTHRACITE COAL.—Where bituminous coal has been subjected to great heat, more carbon and hydrogen are expelled and anthracite coal remains. A similar change takes place where bituminous coal is heated by artificial means. The coke which remains, is, like anthracite coal, nearly pure carbon.

What is humus? How is it produced? 882. PRODUCTION OF HUMUS.—Humus or the vegetable mould of forests, is formed by the decay of wood or vegetable matter in the air. Such decay is a species of slow combustion. The carbon is more slowly consumed than the other constituents. The vegetable mould or humus which remains after the partial decay, is, therefore, like peat, much richer in carbon than the material from which it was produced. It is variable in composition according to the progress of the decay. The access of oxygen from without being unlimited, it is found to remain in equal atomic proportion with the hydrogen.

What is the composition of white rotten wood? 883. WHITE ROTTEN WOOD.—White rotten wood, which forms in stumps and the interior of trees where there is abundant moisture and deficient access of air, has a different composition. The water present becomes chemically combined, and the product may be regarded as differing from the former, somewhat as a hydrated oxide differs from the oxide itself.

How may the decay of wood be prevented?

884. PREVENTIVES OF DECAY.—The tendency of wood to decay is checked by acids, and also by certain salts. For this purpose, corrosive sublimate and chloride of zinc have been chiefly used. The process of impregnation with metallic salts is called *kyanizing*.

How is cloth rendered incombustible?

885. INCOMBUSTIBLE CLOTH.—Cotton cloth immersed in a solution of phosphate of magnesia is thereby rendered incombustible. Silicate of potassa is also used on wood for the same purpose.

What is the effect of sulphuric acid on wood?

886. EFFECT OF SULPHURIC ACID ON WOOD.—Sulphuric acid chars or blackens wood by abstracting a portion of the oxygen and hydrogen which it contains. The carbon is then left in excess, with its characteristic color. This action of sulphuric acid is a consequence of its strong affinity for water, the elements of which it appropriates from most organic substances. Dilute sulphuric acid has another remarkable effect, to be hereafter mentioned.

What is the effect of nitric acid on wood?

887. EFFECT OF NITRIC ACID.—Nitric acid gradually consumes wood and other organic matter, as effectually as if they were burned by fire. The final products of its action are also the same as those of ordinary combustion. This action is accompanied with the evolution of orange fumes, as when the same acid acts on metals. The first effect of nitric acid is to stain wood yellow; for which purpose it is sometimes employed. Nitric acid may also be made to combine with woody fibre, forming gun cotton.

*What is the
effect of
muriatic acid
on wood?*

888. EFFECT OF MURIATIC ACID.—This acid has no very striking effect on wood or other organic substances. But chlorine decomposes and destroys them; principally, in consequence of its affinity for hydrogen, as before explained.

*What effect
have alkalies
on wood and
similar sub-
stances?*

889. EFFECT OF ALKALIES.—Alkalies have the effect of hastening the decomposition of organic substances. This effect is, in part, due to the fact that they promote the absorption of oxygen from the air. Paper or cloth in contact with lime or potash, is found to lose its strength speedily, and finally to crumble away. The theory of this action has already been given in the paragraph on nitrate of lime. Where the atmosphere is excluded, it would seem, from certain experiments, that lime has an opposite effect, and rather retards than promotes the decomposition of organic matter.

*What differ-
ent substances
are contained
in wood vine-
gar?*

890. WOOD VINEGAR.—The acid product, as obtained in the dry distillation of wood, contains, beside acetic acid and water, a sort of alcohol, called wood-spirit, and an oily colorless fluid called *kreosote*. The latter has the odor of smoke, and has the same effect in preventing the putrefaction of animal substances. This effect of smoke is owing, indeed, to the *kreosote* which it contains. A dilute solution of this oil in water is used in medicine and for curing meats.

*What substan-
ces are con-
tained in wood
tar?*

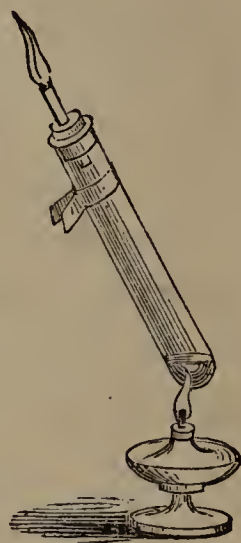
891. WOOD TAR.—Wood tar is a mixture of various oils and volatile crystalline solids composed principally of carbon and hydrogen. *Kreosote*, which is also ob-

tained from wood vinegar, is one of the oils. Another of them, called eupion, has a pleasant odor somewhat similar to that of the flower called *narcissus*. *Pittacal*, a beautiful blue coloring matter, resembling indigo, and *paraffine* resembling spermacetti, are also obtained from tar.

What substances are contained in coal tar?

892. COAL TAR.—Coal tar is produced from bituminous coal in the process of making illuminating gas. It con-

sists of numerous liquid and solid hydrocarbons produced by the decomposition of the coal from which it was formed. Among them is *naphthaline*, like camphor in appearance, and dissipated, like this substance, by exposure to the air. Others are mentioned in the next paragraph. Coal tar, mixed with chalk or other material, is used as a cement, and also as a material for covering roofs.



Mention some useful products of coal tar.

893. USEFUL PRODUCTS FROM COAL TAR.—The first product of its distillation is a light oil commonly known as *benzole*.

This may be substituted for spirits of turpentine for a great variety of uses. Another heavier oil which is obtained from it, is used as a solvent of india-rubber, and also for lubrication and illumination. In Europe, the pitchy mass, which remains on distillation, is employed in moulding refuse coal dust into cakes to be used as fuel. The light oil is also converted by the action of nitric acid into an artificial essence, similar to that of bitter almonds, used exten-

sively for scenting soap. Its vapor, mixed with air, is also burned as gas. The heavy oil may be converted by a different action of the same acid, into beautiful lemon-colored crystals of *carbazotic acid*, a substance now used in France as a yellow dye for silks and wool.

894. OILS FROM COAL.—The oils may be directly produced from bituminous coal itself, and in much larger quantities than from tar, by avoiding the high temperature to which coal is subjected in the production of tar and gas. The production of oils by this means promises to be a very important branch of industry.

895. GUN-COTTON.—This material, so entirely harmless in appearance, has an explosive energy superior to that of gunpowder. It may be prepared by immersing ordinary cotton, for the space of five minutes, in the strongest nitric acid. It is then to be washed thoroughly, and dried at a moderate heat, for fear of explosion. The material is found to have lost a certain portion of its oxygen and hydrogen, in the form of water, and to have assumed nitric acid in its place. It is not however changed in its appearance. A mixture of nitric acid with two-thirds of its volume of oil of vitriol is found to be preferable to pure nitric acid in the above experiment. The oil of vitriol assists in abstracting from the cotton the water which it is desired to replace by nitric acid. Gun-gotton is also called *pyroxyline*. Similar compounds, which are less explosive, may be prepared from sugar and starch.

*What is said
of its proper-
ties?*

896. USE OF GUN-COTTON.—Gun-cotton is not likely, for several reasons, to supersede gun-powder for use in fire-arms. It is much more expensive, and so suddenly explosive as often to burst the barrels in which it is fired. Its explosive force depends, like that of gun-powder, on a sudden combustion throughout its whole substance, and consequent evolution of a large volume of mixed gases and vapor. Of these, carbonic acid, nitrogen and aqueous vapor are the principal.

*What is collo-
dion? How is
it made?*

897. GUN-COTTON SOLUTION—COLLODION.—Gun-cotton dissolves in ether, forming a syrupy liquid which on evaporation leaves behind a transparent, tenacious film. It is used, to some extent, in place of ordinary court-plaster, for covering wounds and protecting them from the air.

*How may wood
be converted
into sugar.*

898. WOOD CONVERTED INTO SUGAR.—Wood may be converted into sugar, by causing it to combine, chemically, with four additional molecules of water. This addition gives it the precise composition and properties of grape sugar, and, in fact, converts it into that substance. Poplar wood is found best suited for the purpose, and can be made to yield four-fifths its weight. To effect the conversion, the wood is first reduced to saw-dust, then moistened with somewhat more than its own weight of oil of vitriol, and left to stand for twelve hours. Being subsequently pounded in a mortar, the nearly dry material becomes liquid. It is then boiled with addition of water, and the transformation is completed. It only remains to remove the sulphuric acid, and evaporate

the syrup. The former object is effected by the addition of chalk and subsequent filtration, and the latter, as usual, by boiling

*How is wood
converted into
gum?*

899. WOOD CONVERTED INTO GUM.—If the boiling be omitted in the above process, the woody film takes the form of a gum, called *dextrine*, of the same composition as the wood itself, but soluble in water. Linen or cotton rags, or paper, may be converted into sugar or gum by the same process. The sugar obtained is the same as that contained in grapes, and is therefore called grape sugar, and also *glucose*. It differs, somewhat, from ordinary cane sugar, as will be hereafter explained.

STARCH.

*What is said
of the compo-
sition and
structure of
starch?*

900. DESCRIPTION.—Starch is identical in composition with wood and gum. It consists of minute enveloped grains, which burst and discharge their contents when swollen by warm water.

*Where is
starch found?*

901.—OCCURRENCE.—Starch is found in abundance in most grains and other seeds; in the tubers of the potatoe plant; in many fruits, and in the pith of certain trees. In greater or less quantity, it is contained in all substances of vegetable origin which are used as food. Horse chestnuts contain 12 per cent. of starch, and have been used in Europe for the production of flour.

*How is starch
prepared from
potatoes?*

902. STARCH FROM POTATOES.—Starch is prepared from rasped potatoes by washing them on a seive. The water becomes

milky, as it passes through, from the fine starch grains which it carries with it. These are allowed to settle, and being collected and dried, are brought into commerce as potatoe starch. A cotton-cloth may be substituted for the seive in this experiment.

*How is starch
made from
wheat?*

903. STARCH FROM WHEAT.—If wheat flour is moistened with water and exposed to the air, it enters into a putrefaction which destroys, in the course of a few days, the other constituents and leaves the starch unaffected. The residue being then washed and dried, the manufacture is completed. Iodine may be used as a test for starch, as described under the head of iodides. Gums and woody fibre, although of the same composition, are not similarly affected.



*How is starch
converted into
sugar?*

904. CONVERSION OF STARCH INTO SUGAR.—Starch, like woody fibre, may be converted into sugar through the agency of sulphuric acid. A dilute acid containing only $\frac{1}{50}$ of its volume of oil of vitriol, is brought to the boiling point, and the starch then added by degrees while the boiling continues. Long boiling is required to effect a complete conversion. An infusion of brewer's malt has the same effect as the dilute acid. The sulphuric acid is then to be removed, and the syrup concentrated as before described. The sugar in this case also is grape, and not cane sugar. Such sugar is manufactured largely in Europe for adulterating cane sugar. In England its manufacture is prohibited by law.

*How is starch
transformed
into gum?*

905. CONVERSION OF STARCH INTO GUM. By keeping the liquid near to the boiling point, without actual boiling, the gum

called *dextrine*, is obtained in the above process, instead of sugar. It may also be prepared by roasting starch, carefully, with constant stirring, until it acquires a brownish yellow color. This gum is used largely in calico printing, for thickening colors. It is also used in making the so-called "fig-paste" and certain other kinds of confectionery. The composition of starch and gum is precisely the same.

*What is said
of natural
gums?*

906. GUM.—Gum arabic and the gum of fruit trees generally, is identical in composition with woody fibre and starch. They are either soluble, like *gum arabic*, in water, or swell up with it to form a thick paste, like *gum tragacanth*. The substance called *pectine*, which causes the juice of currants and other fruits to stiffen with sugar into a jelly, is also similar to the above substances in composition. All of these bodies, like wood and starch, are convertible into sugar by the action of sulphuric acid.

SUGAR.

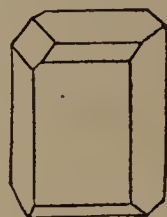
*Where does
grape sugar
occur?*

907. GRAPE SUGAR.—The production of this substance from wood and starch has already been described. It does not exist in the juice of grapes, as its name would imply. The sugar of the grape and other acid fruits contains two molecules less of water. This is spontaneously converted into true grape sugar or glucose, and found in incrustations upon the surface of the dried fruit. Those fruits and trees which have but little acid in their

juice or sap commonly contain cane sugar. The sweetness of honey is due to grape sugar. This variety is much less valuable than that of the cane, from the fact that it has but little more than one-third of its sweetening effect.

What is said of the composition of cane sugar and its artificial production?

908. CANE SUGAR.—The sugar in common use is principally derived from the sugar cane, and thence receives its distinctive name. It differs in its composition from starch, wood and gum, in containing a single additional molecule of water, while grape sugar contains four. It would seem from this composition, that it would be more easily produced by artificial means from starch and similar substances. But this is not the fact. No modification of the process above described, has as yet been devised by which starch and wood can be induced to take one additional atom of water, instead of four. Such a process would be a discovery of the greatest importance, as it would enable us to convert our potatoe and grain fields at will into sugar plantations, and make us independent of foreign supplies. The figure represents a crystal of cane sugar. The form belongs to the fourth system.



What are the principal sources of cane sugar?

909. OCCURRENCE.—Cane sugar is principally produced from the sugar cane, from beets, and the American maple. But it is contained in smaller quantity in the sap of most plants, and in all fruits and vegetables which are not acid to the taste. The production of beet sugar in Europe, in 1850, was estimated at 190,000

tons. That of cane sugar in cane growing countries is incomparably greater.

*How is cane
sugar pro-
duced?*

910. PRODUCTION.—In manufacturing sugar from the cane, the juice is first pressed out between heavy iron rollers, then clarified, and finally boiled down until it will crystalize on cooling. The granular crystals form the raw sugar; the drainings, molasses. Lime is the principal agent in clarification. Its first effect is to neutralize the acid of the juice, which, as before seen, would gradually convert the cane sugar into grape sugar, and thus injure its quality. It also precipitates, with other impurities, the gluten, which, as will be hereafter seen, tends to produce more acid. The methods of producing sugar from the beet and maple are essentially the same. The final purification of sugar by bone black has already been described.

*How may mo-
lasses be con-
verted into
sugar?*

911. MOLASSES.—A large portion of sugar is ordinarily lost in the form of molasses, from which it cannot be made to separate by crystallization. This is owing to the presence of impurities not separated by clarification which interfere with the process in a way not perfectly understood. A method has recently been contrived of avoiding the loss, and thus largely increasing the product of the beet and cane. Baryta added to the syrup combines with the sugar, and takes it to the bottom of the vessel as a solid compound of sugar and baryta, while the impurities remain behind. This precipitate is then removed and diffused in water. Carbonic acid being added, combines with the baryta, and

leaves the sugar to form a pure and crystallizable syrup. Another method of increasing the product of sugar has been described in the section on sulphurous acid.

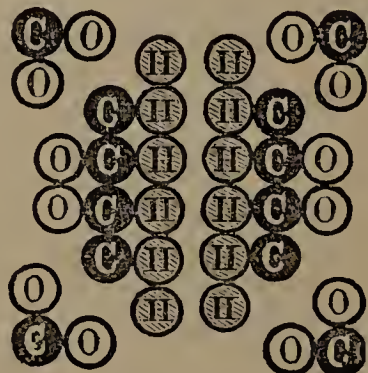
ALCOHOL.

How is alcohol produced from sugar?

912. PRODUCTION FROM SUGAR.—By the addition of brewers' yeast or some similar ferment to sugar, it is gradually converted into alcohol. Two molecules of water are separated in the process. One-third of the carbon and two-thirds of the oxygen which remain, pass off as carbonic acid gas, while alcohol is left. The yeast enters into no combination, and furnishes no material in the process. It acts merely by its presence to effect the decomposition, as will be hereafter explained.

Explain the diagram.

913. In this process of conversion, each molecule of sugar makes two of alcohol and four of the acid. The figure represents a molecule of grape sugar after the removal of two molecules of water. An arbitrary arrangement is given to the atoms for convenience of illustration. On striking off enough carbon and oxygen from the corners to make the required amount of carbonic acid, the residue may be supposed to fall apart into two molecules of alcohol. Alcohol is also produced from cane sugar by fermentation. The first stage in the process is its conversion, by yeast, into



grape sugar. The latter is then changed into alcohol and carbonic acid, as above described.

914. COMPOSITION.—The composition of alcohol appears sufficiently from the middle groups of the preceding figure. According to the theory of compound radicals it is a hydrated oxide of ethyle. The principal group of the annexed cut, represents a molecule of the radical; the remaining circles stand for the oxygen and water with which it is combined in alcohol.



915. PRODUCTION FROM POTATOES AND GRAIN.—Where molasses or solution of sugar is the material used, alcohol is produced as already shown. But when potatoes and grain are employed as the material, a previous process is necessary by which the starch is converted into sugar. This consists in the addition of bruised malt to the mashed potatoes or grain. The *diastase* of the malt has the effect of gradually transforming starch into sugar by its presence, as yeast converts sugar into alcohol. The mixture being kept at a temperature of about 140° , in a few hours the transformation is complete. The starchy mixture has become sweet, and receives the name of *wort*. Brewers' yeast and water being then added to the wort, the conversion into alcohol commences. This is afterward separated from the water and refuse fibre of the potatoe or grain by the process of distillation, described in a subsequent paragraph.

*What is said
of the produc-
tion of alcohol
from olefiant
gas?*

916. PRODUCTION FROM ILLUMINATING GAS.—Alcohol may also be produced from heavy carburetted hydrogen, one of the constituents of ordinary illuminating gas. This is one of the most remarkable results of modern science. Most of the processes of organic chemistry consist in taking apart the complex molecules of organic matter and reducing them to a simpler form, as was illustrated in the production of alcohol and carbonic acid from sugar. Nature, for the most part, jealously withholds from man the power so to direct her forces as to *build up* and produce more complex organic substances by the combination of those of simpler nature. This takes place as a general rule only under the influence of the vital forces of vegetable and animal existence, as when the plant produces sugar from the elements of the atmosphere.

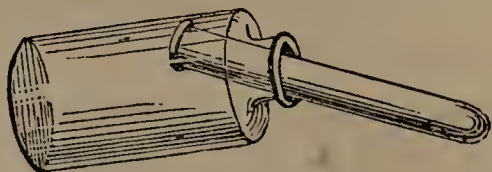
*Explain its
production.*

917. By reference to the central group of the figure, which represents a molecule of heavy carburetted hydrogen, it will be seen that all that is necessary to effect its conversion into alcohol, is the addition of two molecules of water. By long agitation of the gas with strong sulphuric acid, the transference of part of the water which it holds combined is effected. On subsequent dilution and distillation, alcohol is obtained from the mixture. Carbonate of potassa is added in the process of distillation, to diminish the proportion of water which would otherwise pass off with the alcohol. After repeated distillation strong alcohol is thus obtained.



*What is said
of the process
of distillation?*

918. DISTILLATION OF ALCOHOL.—The process of distillation may be illustrated with the simple apparatus represented in the figure. On heating wine, cider or beer in the test-tube, its alcohol will be expelled as vapor and re-condensed as a colorless liquid.



The cooler the vial is kept the more perfect is the condensation. The apparatus commonly employed in the distillation of alcohol, consists of a large copper vessel in which the fermented wort is heated, and a long tube called the *worm*, in which the vapors are condensed. The worm is made to wind in a spiral, through a tub of cold water, that the condensation may be more completely effected. The spirit pours out at the lower end of the worm, where it emerges from the tub. It may be strengthened by repeated distillation. In order to obtain it entirely free from water, a highly rectified spirit is mixed with lime, or chloride of calcium, and re-distilled. These substances have such affinity for water, that they prevent its escape as vapor, while they in no wise effect the distillation of the alcohol. By this means pure alcohol, or absolute alcohol, is obtained.

*What is spir-
its of wine?
Mention some
uses of alco-
hol?*

919. USES OF ALCOHOL.—Ordinary spirits of wine is a dilute alcohol containing but about seventy per cent. of absolute alcohol. The taste and odor of alcohol, its combustible character, and action as a stimulus, are too familiar to need further mention. Its density and

boiling point are given in the Appendix. It is largely used in medicine, and as a solvent of oils and resins and many other substances which water does not dissolve. Medicinal extracts of many roots and herbs, "cologne," and other perfumed liquids are thus produced.

What is the source of the different spirituous liquors?

920. SPIRITUOUS LIQUORS.—Spirituous liquors contain alcohol in large but varying proportion. They differ in their flavor according to the material from which they are produced. Brandy is distilled from wine, rum from molasses, and whiskey from malt^x liquors. The latter name is also given, in this country, to the liquor made from potatoes, corn, and rye. In Europe, the latter are more commonly called brandies.

How are wines produced?

921. WINES.—Wines are produced by the fermentation of the juice of the grape. On exposure to the air, the gluten of the juice becomes a ferment, and causes the conversion of the sugar into alcohol. The addition of yeast is therefore unnecessary. This is also true of the juice of the apple, pear, and other fruits from which fermented liquors are similarly produced.

How is champagne made?

922. CHAMPAGNE.—Champagne and other sparkling wines owe their peculiarity to the presence of carbonic acid in large proportion. This is secured by allowing the last stages of fermentation to proceed in firmly corked bottles, so that all the gas which is evolved is retained. Or an ordinary wine is first produced by the usual process, and sugar and yeast are then added, to excite a new fermentation in the bottled liquid.

+ rye, corn, wheat &c

*What is said
of the pro-
portion of al-
cohol in
wines?*

923. ALCOHOL IN WINES.—Wines differ in the amount of alcohol which they contain; from five per cent., in the weakest champagne, to twenty-five, in the strongest sherry. Those of southern climates are strongest, because the grapes of those regions contain more sugar to undergo conversion into alcohol. Most wines also contain more or less acid and unfermented sugar.

*What is said
of acid in
wines?*

924. TARTAR.—The acid of wine is *tartaric acid*, which exists in combination with potash in the juice of the grape. It gradually deposits in wine casks in the form of acid tartrate of potash or cream of tartar. This separation of tartar is one source of the improvement of wines, and more particularly of the rhenish wines, by age.

*What is said
of the flavors
of wines?*

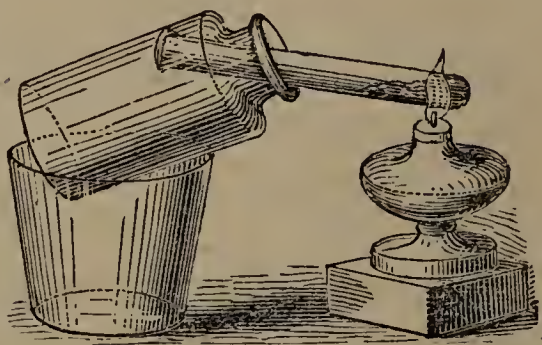
925. FLAVOR OF WINES.—The wine flavor which belongs to all wines, is owing to the presence, in extremely small portion, of an ethereal liquid called *aenanthic ether*. This substance does not exist ready formed in the grape, but is produced in the re-arrangement of atoms which takes place in fermentation. Its vinous odor, when separated from the wine, is most intense. It is prepared in Europe from grain spirit or cheap wines, and is used in this and other countries for producing imitations of wines of higher price. Potatoe whiskey is commonly the basis of these manufactured wines. Beside the general vinous flavor, different wines, like flowers, have an aroma or bouquet peculiar to themselves. These are owing to other and different flavoring substances, present in still smaller proportion than the *aenanthic ether*.

*How are malt
liquors pre-
pared?*

926. BEER AND ALE.—Beer is the fermented extract of malted grain. The *malt* is prepared by softening barley in water, and then allowing it to sprout or germinate. Diastase, which is formed in the process of germination, converts the starch of the grain into sugar, and thus prepares it for the subsequent process of fermentation. Yeast and hops are added to the extract of malt, which is called the *wort*, to bring about fermentation and help to give the product flavor. Ale^x is a similar malt liquor of different color. Porter is a darker variety of beer, made from malt which has been browned by roasting.

*How is alcohol
converted into
ether?*

927. CONVERSION OF ALCOHOL INTO ETHER.—Alcohol is converted into ether by heating with oil of vitriol. To illustrate its preparation, equal volumes of strong alcohol and oil of vitriol may be thoroughly mixed in a test-tube, and the vapors condensed in a cool vial, as represented in the figure.



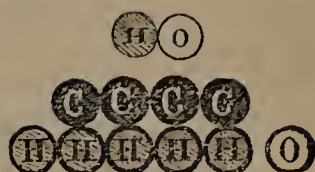
A little sand may be added to the mixture with advantage. The vial should be kept cool by means of paper repeatedly moistened during the process. The space between the tube and the neck of the vial should also be loosely closed with wet paper.

*Explain the
above re-ac-
tion.*

928. EXPLANATION.—Alcohol is, as above stated, the hydrate of the oxide of ethyl. Sulphuric acid combines with the

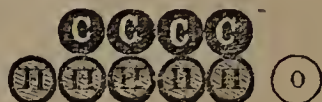
+ It is a weaker (or contains more sugar than)
beer.

oxide itself, on heating, forming a bisulphate, and at a little higher temperature, yields it up again, as gaseous ether or oxide of ethyl. The change



in the alcohol consists, simply, in the loss of an atom of water. The whole figure represents a molecule of alcohol; the lower portion one of ether.

929. PRODUCTION OF ETHYL.—The radical ethyl cannot, like many metals, be directly produced from its oxide. Heat, or other means, applied to accomplish this object, destroys the radical itself. But the end may be reached by a circuitous process. This consists in first producing from the oxide, an iodide of ethyl, and then removing the iodine by a metal. A colorless gas, of the composition indicated by the hydrogen and carbon atoms of the figure, is thus evolved.



How is the radical ethyl procured?

930. CONVERSION OF ALCOHOL INTO OLEFIANT GAS.—The production of alcohol from olefiant gas has been described

in the section on hydrogen. The subject is again introduced for the purpose of illustrating the change, by reference to the atomic composition of the two substances. Representing the atom of alcohol as before, it is converted by the removal of two atoms of oxygen, and two of hydrogen, into olefiant gas. The composition of this gas is indicated by the central group of the annexed figure. The abstraction of oxygen and hydrogen is effected through



the agency of the sulphuric acid used in the process. It will be observed that the radical ethyl, which has remained permanent in the changes before described, is here destroyed by the abstraction of a part of its hydrogen.

What is aldehyde?

931. CONVERSION OF ALCOHOL INTO ALDEHYDE.—Aldehyde is a clear colorless liquid of a peculiar ethereal odor, produced by the action of the air or oxygen on alcohol. It is the product of a partial, slow combustion, or *eremecausis* of the alcohol, and forms the middle point in the conversion of alcohol into vinegar. It is for this reason that it is here introduced.

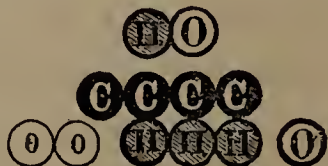


How is alcohol converted into aldehyde?

932. The two atoms of hydrogen which are burned out in the process, are indicated in the figure by smaller inscribed letters. By the removal, the radical ethyl is converted into the radical acetyl. Aldehyde is therefore a hydrated oxide of acetyl. The characteristic odor of the substance is often perceived in the process for making vinegar. It may also be produced by depressing a wire gauze upon an alcohol flame, and thereby making the combustion incomplete.

Explain the conversion of alcohol into vinegar.

933. CONVERSION OF ALCOHOL INTO VINEGAR.—If dilute alcohol is exposed to the air, it is converted, by oxidation, into acetic acid. Part of its hydrogen having been burned out to form aldehyde, the oxygen acts further to oxidize the aldehyde which has been produced. The composition of each molecule is such



as is represented in the preceding figure. It will be observed that the oxygen added is just sufficient to supply the place of the hydrogen removed in the formation of aldehyde. The latter substance being a hydrate of the protoxide of acetyl, acetic acid is a hydrated teroxide of the same radical. The presence of yeast or some other similar ferment, is essential in the production of vinegar as well as in that of alcohol.

Describe the process.

934. PROCESS OF MANUFACTURE.—A

few years since, vinegar was exclusively produced by the souring of wine or cider. At present, large quantities are made from alcohol, by diluting it with water, adding a little yeast, and then exposing it to the action of the air. This is best accomplished by allowing the diluted alcohol to trickle through shavings packed in well ventilated casks. A few passages through the cask suffices to convert the liquid into vinegar. The addition of yeast is unnecessary in producing vinegar from cider or wine, as these liquids contain a substance which acts as a ferment. The vapor of alcohol may be readily converted into acetic acid by contact with platinum black. The property of platinum to produce oxidation in similar cases has been already explained.

How is chloroform prepared? Mention its properties.

935. CHLOROFORM.—Chloroform is best

obtained by distilling pure alcohol with water and bleaching powder. Its molecule consists of two atoms of carbon, and one of hydrogen, combined with three of chlorine. The carbon and hydrogen atoms are regarded as more intimately combined to form the radical formyl. Chloro-

form is therefore a terchloride of this radical. It is a colorless and volatile liquid, of a peculiar, sweetish smell. The inhalation of its vapor produces insensibility to pain, and is much employed in surgical operations for this purpose. Ether has the same effect in a less degree. A mixture of the two is more commonly employed in this country.

936. FUSEL OIL.—Fusel oil is a peculiar kind of alcohol, of extremely nauseous odor and poisonous properties, which accompanies ordinary alcohol in its production from potatoes and grain. It may be separated by filtration through charcoal. But this process of purification is often neglected, and the fusel oil left to add its poison to the deleterious effects of the alcohol itself. It is this doubly poisonous alcohol which forms the basis of numerous manufactured liquors, wines and cordials. Fusel oil is the hydrated oxide of *amyl*. This radical contains ten atoms of carbon to eleven of hydrogen. It belongs to the series of alcohols mentioned in the first chapter of organic chemistry.

What is fusel oil? Mention its properties.

ORGANIC ACIDS.

What is said of the production and properties of acetic acid?

937. ACETIC ACID.—Ordinary vinegar is a dilute acetic acid. It cannot be concentrated by evaporation, as the acid is volatile as well as the water which dilutes it. To obtain the strong acid, recourse is had to the salts of acetic acid, from which it is prepared by the method used for nitric and muriatic acids. The pure

acid is a solid. It mixes with water at low temperature, in all proportions, and is commonly seen in its dissolved state. Its compounds with metallic oxides are called acetates. The sugar of lead, so called, is an acetate, formed by dissolving litharge in acetic acid.

Mention the source and properties of tannic acid.

938. TANNIC ACID.—Tannin, or tannic acid, exists in nut-galls and in the bark and leaves of many trees. It is the principle which imparts to them their astringent taste, and gives to the tan liquor the property of converting hides into leather. When separated from the other substances with which it is combined in nature, it is a yellowish, gummy mass. It is soluble in water, and possesses the property of precipitating glue or gelatin, and many other metallic oxides.

What is the coloring matter of writing ink?

939. WRITING INK.—Common writing ink is prepared from nut-galls and proto-sulphate of iron. When first made, it is principally a tannate of the protoxide of iron, and forms a very pale solution. Before it is fit for use, it must be exposed for a time to the air, and thereby converted, partially, into tannate of the peroxide. This is a bluish black precipitate, and imparts to it the requisite color. It is essential to the permanence of ink, that the change should take place, in part, in the fibre of the paper itself. Too long exposure should, therefore, be avoided in the manufacture. The pale ink thus produced, which blackens further in using, is much more permanent than a thicker, darker ink, produced when this caution is not observed.



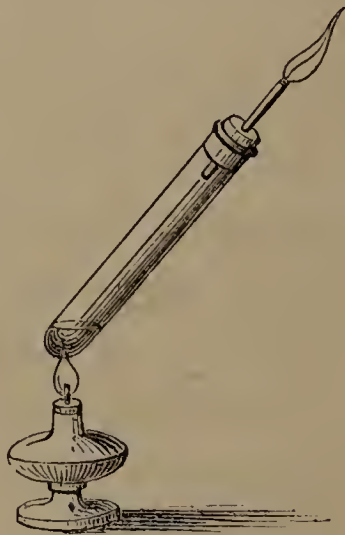
Give the process of its preparation.

940. Six parts of nut-galls to four of copperas, are found to be the best proportions for producing a permanent ink. The galls are to be boiled with water, the decoction strained, and mixed with copperas solution. Gum and cloves are added, the former to keep the coloring matter of the ink from settling, and the latter to prevent its moulding. After a ripening of a month or more the liquid is strained. The coloring matter of ink is immediately produced in a solution of copperas, as a bulky precipitate, by the addition of tincture of galls and a little nitric acid.

HYDROCYANIC ACID.

Mention the composition and properties of cyanogen.

941. CYANOGEN.—Before proceeding with the description of hydrocyanic, or prussic acid, the production of cyanogen, which enters into its composition, will be briefly considered. Cyanogen is a colorless gas, with a peculiar odor resembling that of peach pits. It is nearly twice as heavy as atmospheric air. It burns with a beautiful purple flame. Cyanogen is a compound radical, possessed of important analogies to chlorine and the other electro-negative elements. Its molecule contains one atom of nitrogen and two of carbon.



How is cyanogen prepared?

942. PRODUCTION.—Cyanogen may be expelled from the cyanide of mercury by

the agency of heat. This metal retains cyanogen as it does oxygen, but feebly. A method more commonly employed is to produce and decompose the cyanide of mercury at the same moment. This is effected by mixing chloride of mercury, to furnish the metal, with the double cyanide of iron and potassium, which furnishes the cyanogen. The other elements unite to form chlorides of iron and potassium, while the cyanide of mercury is decomposed as fast as it is formed. The double cyanide of iron and potassium, above referred to, is the commercial *yellow prussiate of potash*. Two parts of this salt are to be heated with one of bi-chloride of mercury, in the above process. The prussiate cannot be used alone for the production of cyanogen, on account of the firm retention of this radical by the highly electro-positive metals which enter into the composition of the salt.

How is cyanide of potassium prepared? Mention its uses.

943. CYANIDE OF POTASSIUM.—Cyanide of potassium is a white substance, resembling porcelain in appearance, and quite soluble in water and alcohol. It is largely

employed in preparing solutions of the precious metals, for galvanic gilding and silvering. It is produced on a large scale, by fusing together carbonate of potash and refuse animal matter. The latter furnishes the carbon and nitrogen required for the production of cyanogen, while the carbonic acid and oxygen of the salt, are principally evolved as oxide of carbon. The cyanide of potassium is best extracted from this residue by alcohol, which leaves the other material undissolved.

How is yellow prussiate of potash prepared? Mention its uses.

944. PRUSSATE OF POTASH.—Cyanide of iron is always incidentally formed from the iron of the vessel in the above process. If water is added to the fused mass, both cyanides dissolve; although the latter, when alone, is entirely insoluble. From the solution, the double cyanide of potassium and iron, mentioned in a preceding paragraph, is obtained, by evaporation, in splendid yellow crystals. It is known in commerce as yellow prussiate of potash, and is largely used in the arts for the production of *prussian blue* and cyanide of potassium. Prussian blue is obtained by adding its solution to a salt of the peroxide of iron. As any solution of iron is readily peroxydized by the addition of a little nitric acid, the yellow prussiate may be employed as a test for this metal.

What is said of ferrocyanogen?

945. FERROCYANIDES.—The yellow prussiate of potash, produced as above described, is not properly a double cyanide of iron and potassium. There is reason to believe that the cyanogen is more intimately combined with the iron than such a name would imply. It seems to have lost its ordinary properties in the compound. Neither the alkalies or sulphide of ammonium, which usually precipitate iron from its solutions, have any power to precipitate it from this salt. The three molecules of cyanogen, which enter into its composition, seem to have hidden and absorbed it. They have formed with it, indeed, a new compound radical, called *ferrocyanogen*. The double salt above mentioned is therefore more properly a ferrocyanide of potassium.

Ferrocyanogen, like all other compound radicals, conducts itself, under ordinary circumstances, as an elementary substance.

What is ferricyanogen?

946. On the removal of one atom of potassium from two molecules of this salt, a coalescence of the ferrocyanogen of the two molecules seems to be the result, and a new compound radical is formed. This radical is called *ferricyanogen*. It combines with the three remaining atoms of potassium, to form ferricyanide of potassium.

Give the properties of prussic acid and its mode of preparation.

947. PRUSSIC ACID.—Hydrocyanic acid is made from cyanide of potassium, by the same method employed for producing hydrochloric acid from common salt. The ferrocyanide of potassium is more commonly employed in the process. Prussic acid is intensely poisonous. A drop or two of the concentrated liquid, placed upon the tongue of a dog, produces immediate death. On account of its extremely dangerous properties, the preparation of the acid should never be attempted except by a professional chemist. The odor of the acid is somewhat similar to that of cyanogen, and may be frequently detected in the vicinity of establishments where galvanic gilding is conducted. Ferrocyanogen and ferricyanogen, like simple cyanogen, have their hydrogen acids and series of salts. The acid of the former is bibasic, and that of the latter tribasic, as already shown by the composition of their potassium compounds.

What is said of citric, malic, lactic, oxalic, and formic acids?

948. OTHER ORGANIC ACIDS.—Tartaric acid, before mentioned, is found in the grape. The acid tartrate of potassa or cream of tartar, which deposits in wine

casks, is one of its most important salts. Another has been mentioned under the head of antimony. Oxalic acid is found in wood sorrel and in certain lichens. It is also prepared by the action of nitric acid on wood, sugar and starch. When these substances are burned in the air, their carbon is converted into carbonic acid. Oxalic acid contains half the proportional quantity of oxygen, and may be regarded as the product of a less perfect combustion by the oxygen of nitric acid. It is a white crystalline solid and a most dangerous poison. The effect of heat on oxalic acid, with its precise composition, is given in the section on Carbonic Oxide. Citric acid is the acid of lemons, malic acid, that of the apple, and formic acid that of the red ant. The latter may also be formed from wood spirit, by oxidation, through the agency of platinum black, as acetic acid is formed from ordinary spirit or alcohol. Lactic acid will be again mentioned under the head of animal chemistry.

What is the composition of the above acids?

949. THEIR COMPOSITION.—All of these acids differ in taste and in various chemical properties, as do those of inorganic chemistry. Yet all of them contain the same three elements which are also contained in wood, gum and starch. They contain these elements in various proportion, but their peculiarities are not to be ascribed to this cause alone. They may be regarded as in part, at least, the consequence of a difference of arrangement of the atoms, as has already been explained.

ESSENTIAL OILS.

What is said of the comparative composition of essential oils ? 950. VOLATILE, OR ESSENTIAL. OILS.—Oils of turpentine and lemon, and otto of roses, are examples of essential oils. They are almost as various as plants themselves.

Yet the composition of those that differ most widely is often the same. This is the case with the oils of orange, lemon, pepper, turpentine, juniper, parsley, citron and bergamot. They contain carbon and hydrogen alone, and in the same proportion; twenty atoms of the former to eight of the latter. Those of bitter almonds, cinnamon, cloves and anise-seed contain oxygen beside. Those of mustard and onions, contain oxygen and sulphur in addition, and are characterized, like all sulphuretted oils, by a peculiar, pungent smell and acrid, burning taste.

How are the essential oils prepared ? 951. OCCURRENCE AND PREPARATION.—Essential oils are oftenest found in the flowers, seeds, and fruits of plants, but sometimes in the stalks and roots. From these they are obtained by distillation with water. The volatile oil passes over with the steam, and floats upon the condensed liquid in the receiver. Oil of turpentine is thus made from the common turpentine, or pitch as it is sometimes called, which exudes from the pine; ordinary rosin remains behind. The delicate perfume of violets and other flowers which contain but a small portion of essential oil, is extracted by mingling the flowers with lard. This substance has the property of absorbing the oil and yielding it again by distillation.

952. USE OF THE ESSENTIAL OILS.—

What are the uses of the essential oils?

The essential oils are extensively employed in the manufacture of essences, perfumes and cordials. All of these liquids are solutions of the oils in alcohol, with the addition, in the case of cordials, of a portion of sugar. The oil of turpentine is used in the manufacture of varnishes and burning fluid, to be hereafter described.

953. BURNING FLUID.—“Burning fluid,”

What is the composition of “burning fluid?”

so called, is a solution of camphene or rectified turpentine in alcohol. The sole object of the camphene is to increase the proportion of carbon, and thus render the flame more luminous. Unmixed camphene may also be burned in lamps provided with tall chimneys. The effect of the chimney is to make a strong draft, and thus provide a liberal supply of oxygen in proportion to the large amount of carbon which the liquid contains. Without this provision, camphene burns like camphor, with much smoke, depositing a large part of its carbon in the form of soot or lamp-black.

954. BURNING FLUID, “EXPLOSIVE.”—

What is said of the explosibility of “burning fluid?”

The mixture of alcohol and camphene, known as burning fluid, is commonly spoken of as explosive. That this is not the fact, may be readily shown by pouring a little in a saucer and inflaming it. It burns, under these circumstances, as quietly as from the wick of a lamp. But if a can, containing burning fluid, be shaken up and then emptied of its liquid contents, it is found to contain an explosive atmosphere. To prove this, it may be tightly corked



and fired through a small hole punched in the side. On applying a lighted taper to the opening, the can explodes with a loud report, and is torn to pieces by the force of the escaping gases. The small proportion of fluid remaining in the can, after every drop that can be poured out is removed, is sufficient to produce this effect.

What is the cause of the explosion? 955. EXPLANATION.—The principle of the explosion is precisely the same as that involved in the same experiment with hydrogen and air. The only variation consists in the substitution of the combustible vapor of alcohol and camphene, for hydrogen gas. It is the mixture of alcohol vapor, and air, to which the effect is to be principally ascribed; the experiment may be made, indeed, as well with unmixed alcohol, or ether, as with burning-fluid. It may also be made with camphene, but in this case the vessel must be warmed, in order to vaporize the liquid in sufficient quantity.

Describe another form of the experiment. 956. The above experiment may be performed with safety, in an open vial, by vaporizing a drop or two of either of the above liquids within it, and then applying a lighted taper to the mouth. In this case, the appearance of flame at the mouth of the vial, and a rushing noise, is all that is observed. This experiment will enable the student to disprove the alleged unexplosive character of certain fluids in use for purposes of illumination. In moderately warm weather it is sufficient to fill the vial, and then to empty it, in order to form the explosive atmosphere.

What is said
of artificial
essences?

957. ARTIFICIAL ESSENCES.—Many of the essential oils are compounds of organic acids and bases. Several of them may be artificially produced. *Pine apple oil* is a compound of butyric acid with ether or oxide of ethyl. The butyric acid of the compound may be prepared from rancid butter or by fermenting sugar with putrid cheese. *Bergamot pear oil* is an alcoholic solution of acetates of the oxide of ethyl with acetate of oxide of amyl. The latter is the ether of the nauseous and poisonous fusel oil, which has before been mentioned.

What is arti-
ficial apple
oil? Artifi-
cial oil of bit-
ter almonds?

958. *Apple oil* is a compound of valerianic acid with the same ether. The valerianic acid of the compound is also made from fusel oil. *Oil of grapes*, and oil of cognac, used to impart the flavor of French brandy to common alcohol, come from the same source. *Oil of winter-green* may be prepared from willow bark and wood vinegar. *Oil of bitter almonds* is prepared from coal tar. These artificial essences, although produced in several cases from poisonous substances, may be used as flavors with perfect safety. It is highly probable and in many cases certain, that the flavor of the fruits themselves, is owing to the presence of these precise compounds in small quantities.

What are em-
pyreumatic
oils?

959. EMPYREUMATIC OILS.—The volatile oils which are produced by the destructive distillation of vegetable and animal substances receive this general name. The oils of wood and coal tar are examples. Another empyreumatic oil is produced in the combustion of to-

bacco in ordinary pipes. This oil is extremely poisonous. It is to be understood that these oils do not exist ready formed in the substances from which they are obtained, but are produced in the re-arrangement of atoms, which takes place when organic bodies are subjected to a high temperature.

*What is the
origin of the
camphors?*

960. CAMPHORS.—Several of the oxygenated essential oils deposit white crystalline solids by cold. These are frequently isomeric with the oils themselves, and are called camphors. Ordinary gum camphor is obtained like the essential oils, by the distillation of the leaves of the *Laurus Camphora* with water. Its volatile character is the occasion of a singular appearance when small bits of the substance are thrown upon warm water. The particles are seen to sail about as if they were possessed of life, owing to the propelling effect of the vapor which escapes beneath them.

*How are re-
sins formed?*

961. RESINS.—The resins, of which ordinary pine *rosin* may serve as an example, are formed by the action of oxygen upon the essential oils. Oil of turpentine may be thus partially converted into resin by long exposure to the air. On subsequently heating it, only a portion is found to be volatile, while a resinous mass remains behind. Turpentine, or pitch of pine trees, is thus formed in nature from the oil of turpentine as it exudes from the trees. But the conversion is only partial, so that the turpentine yields, on distillation, a portion of oil, while rosin remains behind. Resins are easily distinguished from gums by their insolubility in water; they are, on

the other hand, readily soluble in alcohol or ether. They are not liable to decay, like most other substances of vegetable origin. Copal, shellac, mastic and amber are all resins. The latter is found in certain coal mines and at the bottom of the sea, and has probably had its origin in the forests of some primeval age.

Explain the above transformation.

962. EXPLANATION.—The action of the oxygen of the air in the above case is similar to that which occurs in the conversion of alcohol into vinegar. A portion of the hydrogen is burned out, as it were, and removed in the form of water, while another portion of oxygen takes its place.

What use is made of the resins? How are varnishes made?

963. USE OF THE RESINS—VARNISHES.—The resins are principally employed for the production of varnishes. These are simply solutions of resins in alcohol, ether, or spirits of turpentine; or an intimate mixture of the latter with fused resin and oil. In preparing copal varnish, which is the most brilliant and durable, the resin is first fused, then incorporated with heated oil, and afterward diluted with spirits of turpentine. A common varnish for maps, engravings, and similar objects, is made by dissolving mastic with a little *Venice turpentine* and camphor, in spirits of turpentine. Pounded glass is added to the pulverized material during the process of solution. The object is covered with a solution of isinglass before using this varnish, to prevent its absorption. Shellac, in alcohol, is employed to impart to wood or other material a resinous coating,

which is afterward polished with rotten stone. Copal varnish is also similarly used. Shellac, dissolved in soda or potash, is sometimes used to give body to paints, as a substitute for part of the more expensive material.

What is rosin soap? 964. ROSIN SOAP.—The resins possess an acid character, and like fats, form soap with the alkalies. Common rosin is largely consumed, with fat and potash, in the manufacture of common brown soap. The greater hardness which it imparts depends on the formation of a certain portion of rosin soap in the mixture.

How is rosin used in sizing paper? 965. SIZING.—The soap which is formed on boiling rosin with strong potash is used in sizing paper. Being mixed with the material from which paper is to be made, a solution of alum is afterward added to the pulp, and a compound of rosin and alumina thus produced in every portion of the mass. The pores of paper made from this material are thus completely filled, and the spreading of the ink prevented. A surface sizing which is less effectual, is also given to paper by a solution of glue, applied after the paper is formed. When this is destroyed by erasure, its place may be supplied, and the spreading of ink prevented by rubbing powdered rosin upon the spot from which the sizing has been removed.

What is the composition of sealing-wax? 966. SEALING-WAX.—Sealing-wax consists, principally, of shellac. Venice turpentine is added to make it more inflammable and fusible, and vermilion or lamp-black to color it. *Ship pitch* is resin changed and partially decom-

posed by heat. *Shoemaker's wax* is made by a similar process.

What are the products of the dry distillation of rosin?

967. ROSIN OIL AND GAS.—Rosin is partially converted by dry distillation into an oil, which is largely used for adulterating other oils, and also for purposes of illumination. A black pitch remains in the retort. The oil has the advantage of extreme cheapness, but owing to its large proportion of carbon, can only be burned in lamps furnished with tall chimneys. At a still higher temperature rosin is converted into gas, with a residue of carbon.



What is asphaltum?

968. ASPHALTUM.—*Asphaltum* or *bitumen* is a mineral resin, similar to the black pitch which remains from the distillation of coal tar. This material is found on the shores of the Dead Sea, in the island of Trinidad, and in several European localities. It is extensively employed for hydraulic cements, roofing, and pavements.

What is said of the source, composition and properties of petroleum?

969. PETROLEUM.—Petroleum is a liquid hydrocarbon, also known as *rock oil*. It is often found upon standing water, in bituminous coal districts. Pits are also dug for the purpose of collecting it. These become filled with water, upon which the oil rises, more or less abundantly. The rectified petroleum is called *naphtha*, and is a nearly colorless and highly volatile fluid. The entire absence of oxygen in its composition, adapts it perfectly to the preservation of the metals potassium and sodium in their metallic condition.

It is also used as a solvent of sulphur, phosphorus, fats, resins and caoutchouc. Both asphaltum and petroleum have been, probably, produced by the action of volcanic fires upon bituminous coal.

*What is said
of gum re-
sins?*

970. GUM RESINS.—The dried juices of certain plants consist of mixtures of gum and resin. These mixtures are called *gum resins*. Water dissolves the gum, and holds the resin in suspension, thus forming what is called an emulsion. Alcohol, on the other hand extracts the resin from their mixtures. Assafoetida, gamboge and opium are a few examples of gum resins.

*Mention the
sources and
properties of
caoutchouc.*

971. CAOUTCHOUC. GUM ELASTIC.—Caoutchouc is a hydrocarbon obtained from the milky juice of certain trees in Asia, Africa and South America. This constituent of the juice hardens on exposure to the air, while the remainder is removed by evaporation. By the addition of a little ammonia, the milk may be retained in its liquid condition. Caoutchouc is soluble in ether, spirits of turpentine, oil of coal tar, and many other hydrocarbons. Sulphuret of carbon, a volatile liquid obtained by passing sulphur vapors over ignited charcoal, is also a complete solvent of India-rubber and gutta percha.

*How is caout-
chouc vulcani-
zed? What
are the prop-
erties of vul-
canized "rub-
ber?"*

972. VULCANIZED RUBBER.—Heated for a short time with sulphur, at 280° , or somewhat above this point, caoutchouc becomes remarkably changed in its nature, and is no longer stiffened by cold or softened by heat. It is then called *vulcanized*

rubber, and constitutes the material out of which most India-rubber goods are now made. The *hard rubber* which is extensively employed for the manufacture of combs, knife-handles, pencil-cases, &c., is composed of pitch, India-rubber, sulphur, and magnesia. The mixture is softened at about 270° , then pressed into moulds to give it the required shape. It is afterward wrought like ivory.

*What is gutta percha?
Mention some of its properties and uses.*

973. GUTTA PERCHA.—Gutta percha is identical in composition with gum elastic, but possessed of quite different properties. Among them is its extreme toughness and comparatively slight elasticity. It is rendered soft and plastic by immersion in boiling water, and in this pasty condition may be moulded into any required shape. It can be vulcanized, like caoutchouc, and is then proof against elevation of temperature. It is employed as a substitute for caoutchouc where great elasticity is not required. Both of the above substances approach more nearly in their composition to the essential oils than to any other class of compounds.

PROTEIN BODIES—PUTREFACTION—FERMENTATION.

State the composition and properties of vegetable fibrin.

974. VEGETABLE FIBRIN.—The glutinous mass which remains when dough is kneaded in water until all the starch is removed, is called *gluten* or vegetable *fibrin*. It differs from all the organic matter hitherto described, in containing nitrogen, with small quantities

of sulphur and phosphorus. Its exact composition is given in the Appendix. It is a grey substance, and is the material which gives its cohesion to bread.

975. VEGETABLE ALBUMEN AND CASEIN.—

*What is said
of vegetable
albumen and
casein?*

Vegetable *albumen* is a similar substance, contained, in smaller quantity, in the juices of fruits and vegetables. It is coagulated by heat, like the white of egg, when the juices are boiled. Vegetable *casein* is another substance of very similar composition and properties, found principally in the seeds of leguminous plants. It precipitates like the curd in sour milk, when a little acid is added to an aqueous extract of the seeds. These substances derive their names from their resemblance to animal fibrin, albumen, and casein. Vegetable casein is also called *legumine*. All of these substances were at one time supposed to be compounds of a single substance, called *protein*, itself free from both sulphur and phosphorus. Later experimenters have not succeeded in isolating such a substance, and the theory is therefore abandoned. The name is retained in this work as a convenient designation of the class of substances here considered.

976. OCCURRENCE.—One or more of

*Where are the
above substan-
ces found?*

these substances is present in greater or less quantity in all parts of plants. They are found accumulated with starch, in the fruit and seed. The seeds of cereals, such as wheat and rye, and those of leguminous plants, such as peas and beans, contain them in large proportion.

Mention a peculiarity of these nitrogenous compounds.

977. CHARACTERISTICS.—If a bit of gluten be placed on the end of a wire and burned, a very different odor is produced from that of burning starch or wood. The smell approaches that of burning wool, and is a means of distinguishing organic matter which contains nitrogen. If boiled with potassa, the sulphur of gluten is extracted, and the solution will blacken paper moistened with sugar of lead. This reaction furnishes another means of detecting these nitrogenous substances.

Describe the process of putrefaction.

978. PUTREFACTION.—A still more important distinction of nitrogenous substances from those which contain no nitrogen, is their spontaneous putrefaction. Left to themselves, they are resolved, like blood and flesh to which they are allied in composition, into a variety of other products. It is not strictly correct to say that this decomposition is spontaneous. The substance must first have been exposed to the air. An oxidation or slow combustion is then commenced, which, although entirely imperceptible in its effects, and checked at once by exclusion of air, ensures the subsequent putrefaction. It burns out a small portion of carbon and hydrogen, and thus removes, as it were, the key-stone of the arch in every molecule. The atoms may then be supposed to fall together and re-arrange themselves as is required by the known products of their decomposition.

Mention some products of putrefaction.

979. PRODUCTS OF PUTREFACTION.—The re-arrangement which occurs in putrefaction, consists, essentially, in the combustion

of the carbon of the substance with oxygen, while the hydrogen divides itself between the nitrogen, phosphorus and sulphur, forming ammonia, phosphuretted and sulphuretted hydrogen. It is to these gases that the offensive smell which is given off in putrefaction is principally to be ascribed.

What substances are capable of producing fermentation? 980. FERMENTATION.—Any one of the nitrogenous substances above mentioned, while undergoing the change which is called putrefaction, is capable, by its mere presence, of acting as a ferment. A little putrefying gluten, for example, added to a solution of sugar, will convert it into alcohol and carbonic acid. Here again the key-stone of the molecule is removed, or rather in this case *moved*. The motion of the atoms of the putrefying substance would seem to be the cause. The effect is analogous to that of heat, through whose agency, also, complex organic bodies are resolved into others of simpler constitution.

What is the first stage in the process? 981. YEAST.—The first stage in the formation of yeast is the production of a microscopic vegetation, which consumes all the protein, converting it into the substance of a microscopic plant. Ordinary brewers' yeast is such a microscopic vegetation. Being produced, it passes immediately into the putrefaction above described, effecting, at the same time, the conversion of any sugar which may be present into alcohol and carbonic acid. By some, the growth of the microscopic plant itself, instead of its subsequent change, is supposed to be the cause of fermentation.

How is yeast produced?

982. PRODUCTION OF YEAST.—Yeast has not only the power of converting sugar into alcohol, but it at the same time occasions the production of more yeast from dissolved protein. In the ordinary process of beer brewing, the newly formed yeast collects on the surface of the fermenting vats. It is thence removed, to serve as the excitant of a new fermentation, or to be employed in the production of bread, which is, chemically considered, an analogous process.

Mention several kinds of fermentation.

983. DIFFERENT KINDS OF FERMENTATION.—The products of fermentation are different, according to temperature and other circumstances. Thus the same sugar which at 40° to 86° , with cheese used as a ferment, yields carbonic acid and alcohol, at a temperature of 86° to 95° is converted into lactic acid. The latter, by the further action of the curd, with slight elevation of temperature, is converted into butyric and carbonic acids. By the same ferment, at a still higher temperature, a portion of gum is produced with the lactic acid. These different processes of transformation have received, respectively, the names of the vinous, lactic, butyric, and viscous fermentations. The conversion of starch into sugar by diastase may be regarded as a species of fermentation. This substance is a slightly changed gluten. It is always produced in germination, and may be precipitated by alcohol in the form of white flakes from a concentrated infusion of malt. One part of it is sufficient to convert two thousand parts of starch into sugar.

*What is said
of the nutri-
tious prop-
erties of fine
flour?*

984. FLOUR.—Fine flour makes less nutritious bread than the coarser varieties, because it contains a smaller proportion of gluten. Gluten being tougher than the starch, is not reduced to so fine a powder and is partially separated in the process of bolting. All grains contain sugar in small proportion. Sugar is therefore one of the constituents of flour.

*What chemi-
cal principles
are involved
in making
bread?*

985. BREAD.—The “raising” of bread is a process of fermentation. The yeast employed in the process converts a portion of the starch of the flour into sugar, and subsequently into alcohol and carbonic acid. The *sponge* is made light and porous by the gas bubbles which become entangled within it. A large part of the alcohol produced in the process escapes into the oven, and thence into the exterior air. It may be condensed and converted into *spirits* by the proper apparatus. This has been successfully done in large bakeries in Europe, but the process has not been found to be of any considerable economical importance. In baking a small portion of starch is always converted into gum. By moistening the baked loaf with water the gum is dissolved, and by a new heating, hardens into the shining surface which is often observed on bakers’ bread.

*What materi-
als are some-
times substi-
tuted for
yeast?*

986. YEAST POWDERS.—The gas which is needed to make bread light, may be produced by other means than the process of fermentation. If carbonate of soda, for example, is kneaded into the dough, and tartaric acid

subsequently added in proper proportion, the weaker carbonic acid is expelled. A light sponge is produced by its escape, without the loss of the starch and sugar which are consumed in the process of fermentation. Soda and tartaric acid prepared for this purpose are known under the name of *yeast powders*. Carbonate of ammonia being entirely volatile by heat, may be employed alone for the same purpose. A portion of the salt probably remains in the bread, and is more or less injurious on account of its alkaline character.

What is the objection to the use of soda, &c. in bread? 987. TEST FOR YEAST POWDERS.—The great objection to the use of these powders in the preparation of bread, consists in their liability to contain soda or acid in undue proportion. Whether this is the case, may be ascertained by dissolving the powders in water and mixing the solutions. If the product is neutral to the taste and does not effervesce on the addition of either soda or acid, this fact will be evidence of their proper preparation. If otherwise, more or less injury is to be anticipated from their use. Excess of the alkalies especially interferes with the process of digestion, by neutralizing the acids which accomplish it. The use of soda and saleratus with sour milk is liable to the same objections.

What is said, in addition, of their effect on the health? 988. THEIR EFFECT ON HEALTH.—It may well be questioned whether bread prepared by this process is ever as healthy as that made with yeast. For even the neutral tartrate, formed when the materials are used in proper proportion, will tend to neutralize certain stronger acids

which are constituents of the gastric juice. It may thus interfere, in a measure, with the process of digestion. If pure muriatic acid were substituted for the tartaric acid or cream of tartar, this objection would be removed. The product of its action on soda is common salt.

ORGANIC BASES.

Give the names of some of the alkaloids. Why are they so called?

989. ALKALOIDS.—Morphine and strychnine, the former a useful medicine, and the latter, the most dreadful of poisons, are examples of the alkaloids. They are white crystalline bodies but slightly soluble in water. Most of them, like the protein bodies above mentioned, contain the four organic elements; but they differ widely from these substances, in possessing a positive chemical character. They are called alkaloids from their resemblance, in certain properties, to the alkalies of inorganic chemistry. Their action upon vegetable colors is the same; like the alkalies, they also form salts with both organic and inorganic acids. They are, in fact, true alkalies. Their alkaline property does not, however, seem to depend on the oxygen which they contain. Some of them, indeed, do not contain this element. It is highly probable that certain of the alkaloids belong to the class of compound ammonias mentioned in the first chapter of Organic Chemistry.

What is their action on the human body? Their antidote?

990. Their action on the human body does not depend upon their alkaline character, but on other and peculiar properties belonging to each. The salts of the alka-

loids are generally preferred in medicine, in view of their ready solubility. In large doses they are all poisonous. The tincture of nut-galls is employed as an antidote, because of the property of the tannic acid which it contains, to form with most of the alkaloids insoluble precipitates.

991. OCCURRENCE.—*Morphine* is contained in opium, *quinine* is extracted from Peruvian bark, and *strychnine* from the *nuxvomica*. The latter is also the poison of the celebrated *upas*. *Theine* and *nicotine* are other alkaloids, the former of which is found in tea and coffee, and the latter in tobacco. Theine may be obtained, as a sublimate of silky crystals, by moderately heating tea in an iron pot covered with a paper cone.

992. PREPARATION.—Most of the alkaloids may be extracted from the material which contains them by means of acidulated water. A salt of the alkaloid is thus obtained in solution. From this salt the alkaloid may be precipitated, like oxide of iron or any other base, by ammonia. Nicotine is a most energetic poison, falling scarcely below prussic acid in its destructive properties.

COLORING MATTERS.

993. INDIGO.—The vegetable dye-stuffs are extremely numerous. Indigo, madder, and logwood are among the more important. Indigo is deposited from the colorless juice of certain plants by simple exposure to the air. It may be sublimed in

purple crystals by rapid heating. By removing the oxygen absorbed in its production, the original colorless juice may be, as it were, reproduced from commercial indigo. This object is effected by the use of protosulphate of iron, which is converted into sulphate of the peroxide in the process. Caustic lime is at the same time added to dissolve the deoxidized indigo. The colorless solution is employed in dyeing; cloth impregnated with it becomes blue on exposure to the air. A solution of indigo in concentrated sulphuric acid is also employed in dyeing.

What is madder?

994. Madder.—Madder is the ground root of the *rubia tinctorium*. This plant is cultivated extensively in India and Europe. It contains a red dye, produced by the action of the air or certain chemical agents upon the juices of the recent plant. This body is called *alizarine* and may be obtained in beautiful crystals. An infusion of the root in hot water contains a portion of this substance in solution.

What is logwood?

995. Logwood.—This is a red wood, obtained from Spanish America and much employed in dyeing. Its coloring matter is called *hematoxyline*. By evaporating a decoction of the wood and re-dissolving in alcohol, this substance may be obtained, on a second evaporation in the form of yellow crystals.

DYEING.

Explain the theory of dyeing fast colors.

996. DYEING.—Few dyes can be permanently imparted to cloth without the intervention of some third substance, which

shall, as it were, hold them together. Such a substance, with strong affinity for the coloring matter of the dye and also for the fibre of the cloth, is called a *mordant*. The fabric to be dyed being first impregnated with the mordant, is then introduced into the dyer's vat to receive its permanent color.

*What is said
of mordants?*

997. MORDANTS.—Alumina and oxide of iron are the principal mordants employed. They may be “fixed” in the cloth by immersion in the acetates of these oxides. A subsequent exposure for several days to the air is essential, in order that the acetic acid may in part be expelled. A portion of it, however, remains, so that the oxides are, strictly speaking, in the condition of basic acetates. After this exposure, and subsequent washing in hot water, the fabric may be immersed in the dye. An ounce of madder heated with a pint of water will be sufficient for an experiment. The fabric is to be boiled for an hour or more with the unstrained decoction.

*How is the alu-
minous mor-
dant pre-
pared?*

998. PREPARATION OF THE MORDANT.—The solution of acetate of alumina is most conveniently prepared from alum, by the substitution of acetic for its sulphuric acid. This is accomplished by the addition of acetate of lead. Sulphate of lead is at the same time precipitated, and may be filtered off from the acetate which is formed. Three pounds of alum and two of sugar of lead, to three gallons of water, are the proportions to be employed. This mordant produces a red color.

*How are vari-
ous colors pro-
duced from one
dye?*

999. VARIOUS COLORS BY THE SAME DYE.—By the use of different mordants, various colors may be produced from the

same dye. Substitute four pounds of green vitriol for the alum used in the previous case, and the madder gives a deep black. Add four ounces of arsenic with the green vitriol, and a mordant is produced with which the dye will yield a beautiful purple. In the latter case, the solution must be reduced to one-tenth of its original strength by the addition of water.

Describe briefly the process of dyeing with logwood? 1000. DYEING WITH LOGWOOD.—By the employment of the last two mordants, mixed in equal proportions and diluted to half their strength by water, a mordant for dyeing black with logwood is obtained. For dyeing purple with the same material, a tin mordant is used. It may be prepared by dissolving tin in muriatic acid with the gradual addition of nitric acid, then precipitating and re-dissolving with potassa. The cloth being impregnated with this mordant and thoroughly dried, is passed through dilute sulphuric acid, to remove the potassa and leave the oxide of tin. After subsequent drying and exposure to the air, the fabric is ready for the dye.

What are mineral dyes? 1001. MINERAL DYES.—The dyes described in the following paragraphs, are distinguished from those before mentioned by containing no organic matter. They consist of colored salts or oxides precipitated in the fibre of the cloth. Although these substances belong, strictly speaking, to inorganic chemistry, they are here introduced to complete the survey of the subject of dyeing and calico printing.

How is a mineral blue obtained? 1002. PRUSSIAN BLUE.—A mineral blue may be produced by impregnating cloth with the solution of acetate of iron, before

described as a mordant, and then immersing it in an acidified solution of prussiate of potash. Prussian blue is thus precipitated in the cloth. This blue is found to be brightened by passing it through a solution of sugar of lead.

How is a mineral green produced?

1003. MINERAL GREEN.—A mineral green is produced in the same manner by the employment of sesquichloride of chromium, and subsequent immersion in potassa. The color consists of sesquioxide of chromium, precipitated from the chromium salt by the action of the alkali. The solution of sesquioxide of chromium is prepared by the addition of sugar to a solution of bichromate of potassa in dilute sulphuric acid. A part of the oxygen of the chromic acid being abstracted by the organic matter, it is converted into an oxide, which remains in solution.

How is a mineral yellow produced?

1004. CHROME YELLOW.—To produce a mineral yellow, the cloth may be impregnated with acetate or nitrate of lead, then dried and passed through sulphate of soda, to fix the lead as sulphate in the cloth. On finally immersing it in bichromate of potassa, the cloth becomes dyed with yellow chromate of lead. The above process modified by printing instead of saturating with acetate of lead, gives yellow figures on a white ground.

CALICO PRINTING.

How is a white design on dyed goods produced?

1005. WHITE FIGURES.—If it is desired to obtain a design in white, on goods dyed with either of the above madder colors,

the design is printed with a paste of tartaric acid upon the colored cloth. On subsequently immersing the goods in a bath



of chloride of lime, chlorine is evolved in the tissue, and the color discharged only where the acid is printed. The white thus produced is of course in exact correspondence with the printed design.

How are yellow and blue designs obtained on dyed grounds?

1006. PRINTED YELLOW AND BLUE.—To produce yellows on madder red and purple grounds, before described, tartaric acid is printed with the nitrate of lead, and the cloth immersed in bleaching liquid. The color of the printed portions is discharged by the combined action of the acid and bleaching liquor; the lead is at the same time fixed in the cloth as chloride of lead. On subsequent immersion in bichromate of potassa, the yellow figures of chromate of lead are produced as before. For blues on the same colored grounds, a mixture of Prussian blue, dissolved in bichloride of tin, with tartaric acid, is printed on the cloth. The discharge of the ground color beneath the figure, is effected, as before, by chloride of lime.

How are variegated patterns produced?

1007. VARIEGATED PATTERNS.—All of the madder colors which have been mentioned, may be produced upon a single piece of white goods, by printing the different figures of the pattern with different mordants. This is accomplished by passing the fabric between different sets of rollers, each of which is supplied with a paste of the proper mordant, and so engraved that it yields the desired im-

pression. On subsequently introducing the goods into the madder bath, the various colors are developed. The whole piece is at the same time transiently colored ; but the dye may be readily removed from the unprinted portion by thorough washing. A white ground for the colors is thus obtained.

RELATION OF PLANTS TO THE SOIL.

AGRICULTURAL CHEMISTRY.

What mineral substances do plants obtain from the soil ? 1008. The mineral substances which plants obtain from the soil, are known by analysis of the ashes which they yield on combustion. They consist of acids and bases, which enter into the composition of all fertile soils. The bases are potassa, lime, magnesia and oxides of manganese and iron. These are found combined in the ashes with silicic, sulphuric and phosphoric acids, and are accompanied by small proportions of common salt. The carbonic acid which is found in certain ashes is produced in the combustion of the plant. The ashes of all cultivated plants contain the above substances ; but in different proportions according to the nature of the plant. The phosphates predominate in grains ; lime exists in large proportion in grasses ; potash in edible roots ; and silica in straw. The approximate composition of the ash of different plants is given in a table in the Appendix. In estimating the relative proportions of the different constituents which are abstracted from the soil by different crops, the quantity of the crop, as well as the composition of its ash, is of course to be brought into this account.

*Of what are
soils com-
posed?*

1009. COMPOSITION OF SOILS.—Many of the above substances are contained in the soil in extremely small proportion. Soils are principally composed of vegetable matter in a state of decay, with clay, sand and carbonate of lime. The vegetable matter consists of the remains of plants of previous years, and the clay, lime and sand are the product of the gradual crumbling and decomposition of the rocky crust of the earth.

*State the uses
of vegetable
matter in
soils.*

1010. USE OF VEGETABLE MATTER IN SOILS.—The wood, leaves and twigs of which vegetable matter is composed, furnish, in their gradual decay, the potash, silica, and other constituents of their own skeletons to form the framework of new plants. The organic matter is at the same time converted into ammonia and carbonic acid; these constitute the gaseous food on which all vegetable life is sustained.

*What advan-
tage is gained
by the addi-
tion of vegeta-
ble and animal
matter to
soils?*

1011. ADDITION OF VEGETABLE AND ANIMAL MATTER.—The addition of more of this material to the soil, in the form of peat or muck from swamps, is of great advantage, because it increases the supply of the two important classes of materials which have been mentioned. Animal matter of all kinds, whether decomposed, as in stable manure and guano, or in its original condition in the form of flesh, wool, and bones, is a still more valuable addition to the soil. The reason of its higher value, consists in the fact that while it yields most of the other substances which decaying vegetable matter supplies, it furnishes ammo-

nia, which is the rarest and most expensive one, in much larger proportion.

*What purpose
does clay sub-
serve in the
soil?*

1012. USE OF THE CLAY.—The clay in soils serves to retain the ammonia and certain other valuable materials, which would, otherwise, be washed away by descending rains. It seizes not only upon that which comes from the decaying humus, but finds particles in the drops of every shower, which it stores safely away for the future use of the plant. It serves also to retain moisture in the soil, and to impart to it the tenacity by which the roots are enabled to gain a firm hold upon the earth. Soils which contain but a small proportion of clay are for these reasons improved by its addition.

*What is the
office of sand
in soils?*

1013. USES OF THE SAND.—Sand, where it exists in due proportion, gives the proper degree of porosity to the soil, and thus ensures the entrance of the air and fertilizing liquids, and the draining away of all excess of water. Access of air is important, because it brings with it fertilizing ammonia and carbonic acid, and by accelerating the decay of vegetable matter, produces more of these valuable substances.

*What is the
office of lime
on the soil?*

1014. USES OF THE LIME.—The lime in soils, beside serving directly as building material for all forms of vegetation, is the key which unlocks other treasures of the soil and supplies them, also, to the growing plant. The building material which is furnished, as before explained, by the decay of previous plants, is not sufficient. A portion of it never reaches the fields from which it was

originally derived. Exported in the form of grain, or milk, or beef, it returns to the soil in some distant region or is poured into the rivers and the sea through the drains of populous cities. New supplies of potash and other material, are, therefore, demanded by the vegetation of every successive year.

*How does it
accomplish the
object?*

1015. A large part of the materials referred to are locked up in hard grains of granite or other silicates which are found in the soils. Being insoluble in water and the other solvents of the soil, they are inaccessible to the plant. Lime has the property of forcing itself into the rocky prison of every such insoluble grain, and setting part of its inmates at liberty. At the same time it opens the door to the action of other agencies which liberate the rest. They are then floated away in the water which penetrates the soil, and being in due season absorbed, are built into the substance of the plant.

*Give the chem-
ical explana-
tion of its ac-
tion.*

1016. ACTION OF LIME ON MINERAL MATTER EXPLAINED.—The action of lime, which has just been mentioned, is a simple consequence of its basic properties. It takes possession of part of the silicic acid of the alkaline silicate in the rocky grains. Their potassa and soda being now combined with this acid in small proportion, are soluble in the water which penetrates the soil.

*What other
decomposing
agent exists in
soils?*

1017. The water of the soil always contains a certain proportion of carbonic acid. This acid being itself material for vegetable nutrition, has also the property of dissolving those mineral substances which the plant

needs for its support. By the joint action of carbonic acid and water, this transfer is constantly going on even without the aid of lime. But the latter substance very much accelerates the action, and thus adds greatly to the fertility of the soil.

Mention another use of lime on the soil.

1018. ACTION OF LIME ON ORGANIC MATTER.—Lime has another important effect on soils, in hastening the decomposition of their organic matter, and thus, indirectly, supplying in large quantity, valuable materials, before mentioned, which these are adapted to furnish. As this decomposition proceeds in the presence of lime, part of the nitrogen of the organic matter takes the form of ammonia, and part is converted into nitrates, as will be remembered from the chapter on Salts. But the proportion of either is practically immaterial, as both are found to subserve a similar purpose in building up the plant.

How are the above mentioned effects increased? Mention another effect of lime.

1019. All of the effects which have been mentioned, may be regarded as gradually produced in every soil which contains carbonate of lime as a constituent. When it is deficient in quantity, they are, of course, increased by its addition in the form of chalk or marl or limestone. These substances have also the effect of sweetening peaty and marshy soils, which are rendered sour from the presence of too large a proportion of vegetable matter, and thus rendering them fit for cultivation.

In what form has lime the greatest effect?

1020. BURNED LIME.—Burned or caustic lime has all these effects in a much greater degree, and therefore, its extensive use as a fertilizer of the soil. It should be used

cautiously on soils which contain but a small proportion of vegetable matter, for fear that in the more rapid decomposition which it stimulates, it may entirely exhaust the soil of this material. If employed in such cases it should be with admixture of vegetable matter, that the loss which it occasions may be completely replaced.

1021. EFFECT OF ASHES ON SOILS.—

What other substances act similarly? What caution is to be observed in their use?

Potassa or soda applied in the caustic state, or as carbonates, have entirely analogous effects on the soil. They render the insoluble silicates soluble, by increasing in them the proportion of base, and also hasten the decay and conversion of vegetable matter. The admixture of lime or ashes with guano or decomposed manure is to be avoided, because of their effect to expel the ammonia which these substances contain. This may be prevented by previously incorporating the material with a large proportion of clay or vegetable mould, which shall serve as an absorbent of the liberated gas.

What is said of composts?

1022. COMPOSTS.—Composts consist of vegetable and other matter, heaped together for fermentation and partial decay in order to prepare them for application to the soil. In such mixtures, all alkaline materials, including lime, have an effect similar to that which they produce upon the organic matter of the soil.

What is guano?

1023. GUANO.—Guano consists of the accumulated droppings of birds, and is principally obtained from certain rocky islands on the

coast of South America. In these haunts of the heron, flamand, and other sea-fowl, it is accumulated, in some instances, to the depth of a hundred feet. The deposit is usually in smaller quantity, but amounts in the aggregate to millions of tons. The material was employed as a fertilizer by the natives of Peru and Chili long before its introduction into England or the United States for the same purpose.

What is said of different varieties of guano? 1024. DIFFERENT VARIETIES.—The quality of guano differs materially, according to the source from which it is derived.

The ammoniacal salts, on which its agency as a fertilizer principally depends, being soluble in water, the product of moist climates is of comparatively little value. The best is obtained from the coast of Peru, where rain seldom or never falls. The African, Patagonian and other varieties are much inferior.

On what does the agricultural value of guano depend? 1025. AGRICULTURAL VALUE.—The agricultural value of guano lies principally in the ammonia and phosphate of lime which it is capable of yielding to plants.

These constitute, in the best varieties, about one-third of the whole weight. Part of the ammonia is ready formed, and part is produced in the subsequent change which the nitrogenous matter of the guano experiences in the soil. The latter may be produced immediately by a chemical process, and its quantity accurately determined. In estimating the value of guano, it is customary to record the quantity of this *potential ammonia*, as if it were an existing constituent.

*What is said
of the artifi-
cial produc-
tion of ammo-
nia?*

1026. ARTIFICIAL AMMONIA.—The constituents of the ammonia which we purchase in the form of guano at so great expense and bring from distant regions of the earth, exist in unlimited quantity at our very doors. Four-fifths of the atmosphere are nitrogen gas, and the ocean is an exhaustless reservoir of hydrogen. But, strange to say, the chemist with all his skill, cannot, except by circuitous and expensive methods, effect their combination. The discovery of some cheap and ready means of accomplishing this object, would transform the face of the earth, by the unlimited quantity of fertilizing material which it would supply. This result may, perhaps, be reached by patient investigation. But no sudden triumph over nature need be anticipated. Improvements in Agriculture will, as a general thing, be only realized by the earnest co-operation of scientific and practical men, in laborious and oft-repeated experiment.

*What is said
of the exhaus-
tion of soils?*

1027. EXHAUSTION OF SOILS.—When soils become exhausted of those substances which form the mineral food of plants, the growth of vegetation ceases. It is never absolute, but consists in a great reduction of that portion of their material which is in a condition to be appropriated by the growing plant. Such soils are gradually restored by rest. A gradual decomposition of their insoluble material occurs by means of agencies which have before been mentioned, and the soil is thus restored to its original condition. These effects are very much hastened by plowing in such a growth as can

be obtained. Rye, buckwheat, and clover are among the plants best adapted to the purpose. Vegetable matter is thus added to the soil, which, in its decay, hastens the decomposition of the soil itself.

*What is said
of deficiency
in particular
constituents?*

1028. DEFICIENCY OF ONE OR MORE CONSTITUENTS.—The comparative exhaustion of some one or more of the constituents of the soil is a much more frequent occurrence. It is commonly the result of the cultivation of the same crop during many successive seasons, and the consequent reduction of those materials which the particular plant requires in largest proportion. Deterioration of soils from this cause is repaired by an artificial supply of the failing ingredients. It is more wisely guarded against by such a rotation of crops as shall make different demands upon the soil in successive years.

*What is said
of the effect of
decomposing
animal matter
in the soil?*

1029. MAINTENANCE OF FERTILITY.—The effect of decomposing animal matters on the soil has been already considered. They return the very material which was abstracted from the soil, with the addition of nitrogenous matter originally derived from the air by the growing plant. In an enlightened system of rural economy, the production of these materials in large quantity and their careful preservation, is therefore an object of paramount importance. The addition of gypsum or dilute sulphuric acid to fermenting manures, is of great advantage in retaining their ammonia in the form of sulphate and preventing its escape into the air. When additional ammonia is required, it is

most cheaply obtained in the form of guano. The phosphates, whose quantity may be often increased with advantage, are best supplied in the form of “superphosphate of lime.” Other materials are less frequently required. For further information on the subject of the present section, the student is referred to works which treat especially of Agricultural Chemistry.

1030. “ SUPERPHOSPHATE OF LIME.”—

*What is said
of superphos-
phate of lime?*

The method employed in the manufacture of “superphosphate of lime,” has been already given in the chapter on Salts. As in the case of guano, its agricultural value depends on actual or potential ammonia and phosphate of lime. In proportion as the phosphoric acid is in a soluble form, the value is much increased. Additional information on this subject is given in the Appendix.

ANIMAL CHEMISTRY.

CHAPTER III.

ANIMAL NUTRITION.

*How is the
life of ani-
mals sustain-
ed?*

1031. RELATIONS OF ANIMAL AND VEGETABLE LIFE.—The life of animals is sustained by the consumption of material compounded and prepared by the plant, and converted into its own substance out of the materials of the earth and air. This is virtually true even of the carnivorous species, for the animals on which they feed have derived their support from the vegetable world. When they yield their own flesh as food, it is only a changed vegetable matter which they thus supply. All animal matter may therefore be regarded as vegetable matter, more or less modified, or entirely transformed by the processes of the animal body.

*What is said
of the forma-
tion of the
blood?*

1032. FORMATION OF BLOOD.—The blood is, as it were, the river upon which the material required for animal growth is floated to its destination. This complex fluid will therefore first engage our attention. The food having been ground up by the teeth, and moistened by the saliva, is conveyed to the stomach and

submitted to the action of the gastric juice. Here it is converted into a uniform greyish semi-fluid mass called *chyme*. The chyme is pushed forward by spontaneous contraction of the stomach. It yields its nutritious matter, in the form of a milky liquid called *chyle*, to minute absorbent vessels distributed upon the surface of the intestines. Through these absorbent vessels it passes into the general circulation and is converted into blood.

What are the offices of the gastric and pancreatic juices?

1033. TRANSFORMATION OF THE FOOD.

The transformation of the nutritious portion of the chyme into *chyle*, is effected in part by the gastric juice, and in part by the secretion of the *pancreas*. The latter organ lies back of the right end of the stomach, and pours its secretions into the *duodenum*, or first of the small intestines. The gastric juice dissolves the protein compounds of the food, while the secretion of the pancreas transforms the sugar and starch of the food into grape sugar. The chyle is thus perfected and prepared to be drawn off from the refuse portions of the food. As sugar forms no part of healthy blood, we must suppose that it undergoes immediate transformation into fat or other material as soon as it enters the circulation. The office of the bile which is secreted by the liver and poured into the intestines, is not thoroughly understood.

To what is the solvent agency of the gastric juice due?

1034. THE GASTRIC JUICE.—The saliva which is mingled with the food in mastication, has an effect similar to that of the secretion of the pancreas. Another of its

probable agencies is to introduce air into the stomach, to act upon its lining membrane and produce from it one of the constituents of the gastric juice. The solvent agency of this fluid is in part owing to the ferment thus formed, and in part to the free acids which it contains in solution. The latter are phosphoric, hydrochloric, butyric and lactic acids, in part free, and partly in the form of salts.

1035. COMPOSITION OF THE BLOOD.—

Give the composition of the blood.

If fresh blood is beaten with a branched stick, it is separated into a slightly alkaline liquid called the *serum*, a fibrous material called *fibrine*, and red globules, which sink, after a time, to the bottom of the vessel. The fibrine adheres in threads to the stick with which the operation is performed. It is analogous in composition and properties, to the vegetable gluten from which it is formed. The serum contains albumen, and resembles the white of egg. The globules are also principally albumen, with a small proportion of a red coloring matter called *hematosine*. Albumen and fibrine both contain phosphate of lime or bone earth. The serum contains, also, certain salts, and a small proportion of fat. All of these substances together form but about one-fifth of the blood; the remaining four-fifths are water. When blood is left to stand, after being drawn from the body, the fibrine coagulates spontaneously, entangling and taking with it the red globules, and thus separating them from the serum.

1036. ANIMAL NUTRITION.—It is evident

What materials are found ready formed in the blood?

from the preceding paragraph that much of the material required to build up the body is found ready formed in the blood.

It has been transferred to it from the vegetable world without material change in composition. Thus the fibre which is required for muscle, and fat to fill out the tissues, require only to be built into their places in the animal frame, as a mason lays up a wall from materials provided to his hand. For the production of other animal substances, essential changes are required. The power of selection and appropriation of the proper materials for every organ and every secretion, is found to reside in innumerable minute cells, which are distributed in every part of the body, and are endowed with peculiar powers according to the offices they are designed to fulfill.

BONES, FLESH, &c.

1037. BONES.—Bones consist of earthy matter and a cartilagenous material commonly known as *gelatine*. The bone earth or mineral matter is principally phosphate of lime, and forms in mammiferous animals about two-thirds of the whole weight. The remaining third is cartilage. Either of these constituents may be removed from the bone without effecting its shape. By removal of the cartilage, a brittle, earthy framework remains. By removal of the earthy material, a perfectly flexible mass is obtained, of a form entirely similar to that of the original bone. The first change may be effected by long digestion in dilute muriatic acid, and the latter by fire. If in the second process the cartilagenous matter is not entirely consumed, bone black

What is the composition of bone? How is it shown?

or animal charcoal is produced, the uses of which have been already described.

*Of what does
flesh consist?* 1038. FLESH.—Lean flesh or animal muscle is composed of fibrine, penetrated by a liquid which forms four-fifths of the whole, and is called flesh fluid or juice of the flesh. It contains a peculiar organic acid possessing the flavor of broth, crystalline substances called *creatine* and *creatinine*, and certain salts. Being extracted by cold water and then heated, it forms a nourishing and highly flavored soup. Hot water coagulates its albumen and prevents its escape from the flesh. Gradual heating is on this ground to be recommended in the preparation of soups, while sudden exposure to a high temperature, both in boiling and roasting, yield more nutritious and highly flavored meats. The salts of potash prevail in the flesh fluid, while those of soda are more abundant in the blood. Unlike the blood, this fluid is acid in its reaction.

*What is said
of tendons and
ligaments?* 1039. SKIN, TENDONS, LIGAMENTS.—The cartilaginous material above mentioned as a constituent of bones, is transformed by boiling water, without change of composition, into gelatine or glue. The skin, cellular membrane, tendons and ligaments of the body undergo the same change, and yield the same product. Gelatine may even be prepared from refuse leather, by first extracting the tannin, and thus reducing it to the condition of the original hide. The tannin obtained in the process may also be employed for tanning new hides. Hoofs, hair, horn and feathers, although very similar substances, are not thus affected by boiling.

What is gelatine?

1040. GELATINE.—Gelatine is soluble in water, and yields a stiff jelly on cooling from a hot solution. On this property is based its use in the preparation of jellies for the table. The commercial article employed for this purpose and ordinary glue are essentially the same.

Give the composition and properties of gelatine.

1041. The substance known as *isinglass*, is the dried air bladder of a species of sturgeon, and forms in its natural condition a soluble gelatine. Gelatine contains the four principal organic elements; nitrogen and oxygen being in somewhat larger proportion than in the protein bodies. Hoofs, hair, and the other substances above mentioned, contain sulphur in addition. Gelatine is susceptible, like the protein bodies, of putrefaction, and also of exciting fermentation. As starch is changed into sugar by the action of dilute sulphuric acid, so by the action of oil of vitriol, gelatine may be converted into a sweet crystalline substance called *glycocoll* or sugar of gelatine.

What chemical combination occurs in tanning?

1042. HIDES, TANNING.—A solution of gelatin forms with tannin or tannic acid a tenacious insoluble precipitate. The tanning of leather depends on the formation of this insoluble compound in the hides which are submitted to the process. They are immersed for this purpose in an infusion of oak and hemlock bark, until the combination has taken place throughout the whole thickness. They are thus secured against putrefaction and converted into firm, elastic leather. Hides may



also be preserved by soaking them in alum and afterward in oil. Soft chamois' leather is prepared by working the skin with fat alone.

FATS.

*What is said
of the consti-
tution of fats?*

1043. COMPOSITION.—We have already seen that there are both acids and bases of purely organic origin, and that these may combine like the similar compounds of inorganic chemistry, to form salts. The animal fats and oils are mixtures of such compounds in different proportions. The principal of these organic salts are *stearine*, *margarine*, and *oleine*. Stearine is solid, oleine fluid and margarine occupies a middle position between the two. The difference of consistence in butter, lard, and tallow, is owing to varied proportions of these three substances which enter into their composition. Beside the fats contained in other parts of the body, the brain and nerves of animals contain, with albumen and water, certain peculiar acids and fats.

*How may the
constituents of
oil be separated?*

1044. SEPARATION OF FATS IN OIL.—The stearine and oleine of whale oil separate spontaneously in cold weather. The cold which is sufficient to harden the former, leaves the latter in a fluid condition. This effect is often observed in lamps during winter weather. The case is quite analogous to the separation of cider into alcohol and water by freezing. The water congeals, and leaves the alcohol fluid. Both separations are imperfect. As the alcohol produced by the above process

is diluted to a large extent with water, so the oleine retains a considerable portion of stearine in solution.

1045. SEPARATION OF FATS IN TALLOW AND LARD.—*Stearine* is obtained from lard and tallow on a similar principle. It hardens on partially cooling the melted fat, forming a mass from which the fluid oleine may be separated by pressure. Stearine thus obtained is used in the manufacture of candles, while the oleine forms lard or tallow oil. The former has, of late years, given place to stearic acid, procured from the same sources by means to be hereafter described. Margarine may be separated from butter by similar heating and slow cooling. It is regarded by some chemists as a simple mixture of stearine and oleine and not a distinct substance.

What is glycerine? How is it made?

1046. GLYCERINE.—*Glycerine* is the base of all the fatty salts which have been mentioned. It is a viscid, sweetish liquid containing the same elements as grape sugar, and in nearly the same proportion. On removing the stearic, and oleic acids from melted stearine or oleine, it remains in the liquid form. This removal may be effected by lime. The white lime compound floats upon the water which is used in the process, while glycerine is dissolved.

How is stearic acid made?

1047. STEARIC ACID.—The compound formed by lime, as described in the last paragraph, if tallow has been used in the process, is a mixture of *oleate* and *stearate of lime*. From these, *stearic* and *oleic acids* are liberated by the agency of

diluted oil of vitriol. The material floats on the dilute acid, gradually losing lime and becoming transparent by its action. Sulphate of lime or gypsum is formed at the same time and sinks to the bottom of the vessel. The stearic and oleic acids are drawn off while yet warm, and run into cubical moulds. The latter is subsequently removed from the mixture by gentle heat and pressure. The remaining stearic acid is then remelted and allowed to cool slowly. It is thus obtained in a brilliant white mass, of crystalline texture, with the lustre of mother of pearl. This material is principally employed in the manufacture of candles. Its superiority to stearine for this purpose, consists in the fact that it is less softened by heat. The two substances differ in their melting point about ten degrees.

*How are pot-
ash and soda
soaps pre-
pared?*

1048. SOAPS.—Soaps are compounds of stearic and oleic acids with caustic potash or soda.* They are produced by boiling fats with either of the alkalies, till the mixture becomes nearly or quite transparent. The glycerine which is expelled from the fats in the process, remains mixed with the soap which is produced. Potash soaps are soft. Soda soaps may be converted into a floating coagulum, and separated from the water used in their preparation by means of common salt. This method is employed to give them their hardness. The action depends on the insolubility of the soap in salt water. Salt added to potash soap seems to have the

* In the ordinary preparation for soap making, the lye is made to pass through lime in the leach tub, that its carbonic acid may be partially removed.

same effect. But its action in this case is due to a double decomposition, in which a floating soda soap is formed, chloride of potassium remaining in solution. Soaps may be also made without the use of water, by combining oil or fat with melted potash.

How are transparent soaps and liniments prepared?

1049. LINIMENTS, &c.—Soaps are soluble in alcohol, forming the *tincture of soap* which is used for bruises. With the addition of camphor, this tincture forms *opodeldoc*. Transparency is imparted to soap by the evaporation of an alcoholic solution of the well dried material. *Liniments* are soaps prepared from ammonia and oil by the simple agitation of the materials.

Explain the cleansing action of soap.

1050. PROPERTIES OF SOAPS.—Soaps which are prepared, as above seen, from oils and fats, have the property of dissolving more of the same material. On this property their cleansing effect principally depends. When they are dissolved, a portion of the alkali becomes free by the substitution of water as base. This free alkali adds to the cleansing effect, by its own affinity for the oils and other organic matter. Alkalies alone are not equally effectual; they tend to shrink the fibre of cloth, and thus protect it against a perfect purification. The strength of the tissue is at the same time gradually impaired.

MILK, BUTTER, &c.

What is the composition of milk?

1051. MILK.—Milk is analogous to blood in composition, as is implied in the office which it fulfills in the nutriment of

the young animal. But casein takes the place of the fibrin of the blood, and fat is also found in milk in much larger proportion. This fluid also contains sugar, which is peculiar in its character and has therefore received the name of *sugar of milk*. Butter is produced by the coalescence of the small particles of oil which are suspended in milk, and partially separated in the cream. Chemically considered, it is a mixture of oleine and margarine. On partially cooling melted butter, the latter collects at the bottom of the liquid oleine, which forms the other constituent; a portion at the same time remains in solution. Beside the above substance, butter contains phosphates and other salts, with certain neutral fats from which it derives its flavor.

1052. CHEESE.—On exposure to the air
Why is the curd separated by exposure? for a considerable time, the sugar contained in milk is partially converted in lactic acid, and the casein is precipitated. One reason of this precipitation is to be found in the neutralization of the free alkali of the milk. The casein having thus lost its solvent assumes the solid form. The coagulation of milk may also be effected by *rennet*, which consists of an infusion of the lining membrane of the stomach of the calf. Its mode of action is not well understood.

1053. SOLID MILK.—Milk may be
How is solid milk prepared? brought into the solid form by careful evaporation with a moderate heat. It must be constantly stirred during the process. A machine has been recently patented which secures all of

these objects. With the addition of a little soda and gum, milk may be thus kept sweet in the solid condition for many months. The addition of water is all that is necessary to reproduce it in its original form.

CHEMICAL CHANGES IN THE ANIMAL BODY.

What is said of changes in the animal body? 1054. Certain important changes which are constantly occurring in the animal body remain to be considered. The body is not the same in any two successive moments of its existence. Every breath exhales a portion of its substance into the atmosphere, and every effort, whether of brain or muscle, is accompanied by some transformation in the material of which it is composed.

Mention certain changes in the blood? 1055. CHANGES IN THE BLOOD.—By comparing the blood of animals with their food, it will be evident that certain materials have been not only modified, but entirely transformed in its production. Starch and sugar are important constituents of the food, but they form no part of healthy blood. They are transformed into fat or other material as soon as they enter the circulation, and in this new form constitute the fuel from which the heat of the animal body is derived. Other changes which occur in the blood will be mentioned in subsequent paragraphs.

What is the source of animal heat? 1056. ANIMAL HEAT.—The oxygen which is necessary for the slow combustion of the material above mentioned, is taken into the blood in the course of its passage through

the lungs. It passes on with them, through the arteries, into the minute capillary vessels which are distributed throughout the body. In these vessels their combination takes place, with the same production of carbonic acid and evolution of heat, as if the material were burned in air or oxygen gas. The carbonic acid thus formed is carried back to the lungs in the venous blood, and there exhaled, through the thin membrane of the air cells, and exchanged for a new supply of oxygen gas. In view of the relations of starch and sugar to the process of respiration, as above shown, they have been termed the *respiratory constituents* of the food.

*What is said
further of res-
piration?*

1057. RESPIRATION.—In cold weather a larger amount of oxygen is inhaled with every breath, in consequence of the greater density of the air. Respiration is also involuntarily hastened, and the blood, from the two causes combined, becomes more thoroughly impregnated with oxygen gas. The transformation or combustion of the respiratory constituents of the blood, proceeds more rapidly in consequence, and more internal heat is produced to oppose the external cold. This is one of the provisions of nature by which the animal body is enabled to resist the influence of the seasons and of climate. Labor has the same effect as cold in hastening respiration and necessitating a larger supply of food.

*What change
of color does
the blood ex-
perience in the
lungs?*

1058. CHANGE IN COLOR OF THE BLOOD. From the fact that the globules of the blood undergo a change of color in the lungs, where oxygen is absorbed, it is presumed that they serve, by absorption of the gas, as the

medium for its conveyance through the body. As a consequence of the changed color of the globules, arterial blood is of a bright scarlet, while venous blood is dark red. The same change of color which takes place in the lungs, may be readily produced by agitating blood drawn from the veins with air or oxygen gas.

*What is said
of the rela-
tions of food
and tempera-
ture?*

1059. RELATIONS OF FOOD AND TEMPERATURE.—In proportion as the draft of a furnace is increased, more fuel must be supplied for its combustion. For the same reason more respiratory food must be taken into the system, in proportion as more atmospheric oxygen is inhaled. The fact that a larger quantity is required in northern climates thus receives a scientific explanation. The preference entertained in arctic regions for certain kinds of food, is also accounted for by the same necessity for increased resistance to the external cold. The train oil and fat which the Greenlander consumes with avidity, are a better fuel in the animal body than the starch which forms a principal part of the food consumed in warmer climates. The chemical reason of this difference is found in the fact, that starch and allied substances contains oxygen in larger proportion. They are, as it were, in their natural condition, partially burned or oxidized substances.

*What change
takes place in
the tissues of
the body?*

1060. CHANGE OF THE ANIMAL TISSUES. In proportion to the muscular or nervous activity of the animal, the substance of the body is disorganized and returned to the blood from which it was produced. From the

blood it is finally removed by the kidneys, principally in the form of *urea* and *uric acid*, and thrown off as waste material from the system. These substances, although organic, may be figuratively regarded as the ashes of the consumed muscle and other nitrogenous constituents of the body. A portion of the carbon and hydrogen of the animal organs has at the same time disappeared, like the elements of respiratory food, in the form of water and carbonic acid.

What is said of Urea? 1061. UREA.—Urea, when separated from its solution, is obtained as a white crystalline solid. Its molecule contains four atoms of hydrogen, to two each of carbon, nitrogen, and oxygen. When left in contact with the mucus with which it is accompanied in the secretion of the kidneys, it is speedily converted, by combination with four molecules of water, into carbonate of ammonia. Urea may also be artificially produced from cyanic acid and ammonia. This cyanate is identical with urea in composition, and is converted into urea by solution in water and evaporation. It was among the first of organic bodies artificially produced. Uric acid contains the same elements with a larger proportion of oxygen, and also yields ammonia by its decomposition. Besides the above substances, the secretion of the kidneys contains various soluble salts, which have formed part of the body. The insoluble salts are removed from the system by other means.

What is said of the disappearance of fat? 1062. DISAPPEARANCE OF FAT.—STARVATION.—When the supply of respiratory food is deficient, nature avails herself of the fat previously stored in the animal

body, as fuel to sustain the animal heat. It is taken up by the blood, and burned in the capillary vessels, as before described. This happens in the case of the bear and other hybernating animals. Lying dormant during the winter season, their fat is consumed, and they emerge lean from their dens in the spring. Where food is deficient and there is no accumulation of fat to supply its place, the muscle and other portions of the body are consumed, and death by starvation is the consequence.

1063. REPAIR OF THE TISSUES.—As fast *How are the tissues repaired?* as the worn out matter of the muscles and other organs is removed, its place is supplied in the healthy body by new material from the blood. Through it, also, the phosphates of the soil and the vegetable world are transferred to the skeleton of the animal, and in smaller proportion to other parts of the frame. The blood is itself renewed by the materials of the food.

1064. VARIETIES OF FOOD.—It is implied *Mention two classes of food.* in the foregoing, that the two classes of substances which enter into the composition of the food of animals, subserve very different purposes in the animal economy. The first class, of which starch and sugar are the principal, serve, by their gradual combustion, to sustain the animal heat. They are included, as above stated, under the general name of *respiratory food*. The protein bodies, on the other hand, all of which contain nitrogen, are appropriated in the formation of blood and muscle; they make up the *sanguineous* or *plastic* food. In view of the fact

that the respiratory food enters also, in a changed form, into the composition of the blood, the former term can scarcely be regarded as distinctive. The latter, which designates the office of the protein bodies in furnishing material to build up the organs of the body, is much to be preferred.

*What is said
of the import-
ance of due
proportion of
the two kinds
of food?*

1065. PROPORTIONS OF FOOD.—For the economical sustenance of animals, it is of importance that a proper relation of quantity should be maintained between these two varieties of food. Respiratory food alone,

provides no material for supplying the waste of the organized tissues. Plastic food, on the other hand, is especially adapted to this end, but is poor fuel for sustaining the heat of the body. Yet in lack of other material, it is diverted from its natural use, and thus appropriated at great economical disadvantage.

*What does na-
ture teach on
this subject?*

1066. Nature teaches us something on this subject, in the composition of milk and those grains which constitute the principal food of man. It will be found by reference to the table in the Appendix, that the quantity of respiratory matter in these substances, is from three to six times greater than that of the plastic material. When the object is to fatten an animal, the proportion of respiratory matter may be considerably increased by the use of potatoes, rice and other farinaceous food. Being furnished in excess, it accumulates in the body in the form of fat. Working animals, on the other hand, must be supplied with nitrogenous or plastic

food in large proportion. The use of bacon with peas, beans, and eggs, and many other popular mixtures of food, are accounted for on the principle above stated. For the development of most of the views presented in this chapter, the world is indebted to the distinguished Liebig.

ORGANIC ANALYSIS

How are carbon and hydrogen determined?

1067. ULTIMATE ANALYSIS. CARBON AND HYDROGEN.—The proportions of carbon and hydrogen in organic substances, is ascertained from the quantity of carbonic acid and water which they yield on combustion. The combustion is effected in a glass tube, by means of oxide of copper, and the products are collected by means similar to those described in the process for analyzing the air.

How are nitrogen and oxygen determined?

1068. NITROGEN AND OXYGEN.—The proportion of nitrogen in an organic substance is usually determined by the quantity of ammonia it will yield by combination with hydrogen. This combination is effected by heating the organic substance with hydrate of potassa or soda. The quantity of the ammonia produced in the process is estimated by the amount of acid it will neutralize. From the weight of this compound, that of the nitrogen it contains is readily calculated. The amount of oxygen in an organic substance is ascertained by subtracting the total weight of all the other constituents.

How are organic bodies separated from each other?

1069. PROXIMATE ANALYSIS.—When it is desired to separate organic bodies from each other, and determine their relative proportion without reference to their elementary composition, the methods are analogous to those of inorganic chemistry. Distillation, and the analysis of the fats, which have been already described, may be taken as examples.

CHAPTER IV.

CIRCULATION OF MATTER.

*What proves
the relation
of the three
kingdoms of
nature?*

1070. The relations of the three kingdoms of nature have been already incidentally considered in former parts of this work. It remains to present the subject in a single view. It is obvious, at a glance, that the soil does not furnish all the material which is required for the wants of vegetable life. The level of our meadows is not lowered by removal of successive crops, nor does the forest dig its own grave at its roots as it lifts its ponderous trunks into the air. The atmosphere, as well as the soil, contributes to the increase of mass, whether of wood or grain, and indirectly feeds all races of animal existence. The relation of the three kingdoms of nature is thus established.

*How does wa-
ter serve in
the circulation
of matter?*

1071. Water is one of the principal agents in the system of circulation of matter, which constitutes the life of the globe we inhabit. In the fulfillment of its office, it passes incessantly from sky to earth, now mingling with the currents of the atmosphere, and anon with those which form the arteries and veins of the great world of waters. Lifted into the atmos-

phere by the sun, it descends again in dew and rain, corroding and dissolving the rocks on which it falls, and distributing them widely over land and sea.

What distinct office does it fulfil? 1072. It settles through the stony crust of the earth, into the dark recesses of the rocks where crystals blossom out of the formless stone, and supplies them with the material for their wonderful architecture. It penetrates the soil, and supplies the same material to the roots of plants for the still more wonderful creations of leaf, and fruit, and flower. Again it hastens through brooks and rivers on its course, and pours its burden into the sea, for the use of the innumerable forms of vegetable and animal life which inhabit its waters. The coral insect builds up solid islands out of the matter it provides. Countless shell-fish clothe themselves in the same rocky garments, and finally cast them aside, to be buried under the slime of the sea and harden, in the course of ages, into stone. The water which has served these various offices, climbs anew into the heavens upon the solar rays, and again descends in the rain, repeating forever its round of service to the earth.

How may the further relations of the three kingdoms be illustrated? 1073. The further relations of the three kingdoms of nature may be presented in a single picture. Imagine a giant tree, the representative of all the vegetation of the earth, spreading wide its branches as a shelter for man and beast. Let us suppose them to subsist entirely upon its fruit, and to warm themselves by fires made from its branches. The tree, through its leaves,

draws its supply of gaseous food from the atmosphere, and through its roots, its mineral sustenance from the soil. It has purified the air in the process, of gases which would become noxious by accumulation, and returned to it the oxygen which is the vitalizing breath of the animal world. The mingled material of its food, worse than worthless to animals, has, at the same time, been transformed into wood and fruit, and other forms of vegetable matter.

*Explain the
return of mat-
ter to the at-
mosphere.*

1074. At this point, without interruption in the circuit, commences the return of material to the atmosphere from which it was derived. Animals that feed upon the fruit of the tree, already breathe much of it back again to the air while they live, and the rest is restored by their death and subsequent decay. Leaves that fall and moulder, and branches that are burned as fuel, make the same return of the elements of which they are composed, to the great reservoirs of the atmosphere and earth. And what happens thus to leaf and fruit, happens also at last to the parent tree itself. One by one its giant branches fall and moulder, and melting again into the air, add to its inexhaustible stores of fertility, and provide the material for a new round in the grand system of circulation.

*Illustrate the
extent of these
relations.*

1075.—What happens beneath the single tree, occurs also in every flower that lifts its petals to the sun, and is a thousand times repeated in every forest upon the face of the earth. No limits of distance or of size restrict the mutual relations and dependencies of nature. The exhaled carbon

of the polar bear feeds the lotus of Egyptian plains, and the breath of the southern lion is redistilled in the fragrance of the Norwegian pine. The particle of matter that once burned in the fire of the poet's brain and floated with his song upon the air, now blooms in the mountain flower and anon lies buried in its mould.

What is the material source of the life of the world?

1076. According to the view thus presented, it will be seen that the sun is the great material source of the life of the world. He wings the vapors that rise from the sea, and fall again to make their ministering circuit in the earth. The solar rays are the agents also, in the transformation of matter, which takes place in every leaf and blossom, and provides the animal kingdom with its food.

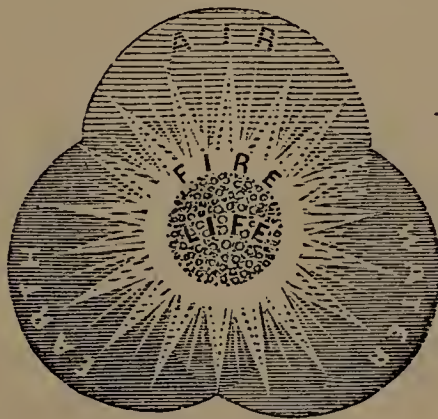
Show how it is the source of mechanical power.

1077. No less is the sun the source of all the mechanical power which is known upon the earth. The falling flood of Niagara is but the recoil of the spring which is bent in evaporation from the sea and earth. All force which is derived from the fall of water, is thus traceable to the sun, which lifted it in the form of cloud and vapor. The energies of fire and steam, are only other forms of the force inherent in the solar rays, originally exercised in the organization of the vegetable matter which serves as fuel. Immediately produced by oxidation and the heat which it evolves, they find their ultimate source, as well as their precise equivalent, in the deoxidizing influence of the solar rays. The forces of the human body are fed by consumption of similar materials, and may therefore be traced to the same source.

*What further
influence has
the sun?*

1078. Every planet that surrounds with its orbit the great centre of our system, is equally dependent upon his influence.

Held in their courses by his attraction, and encircling him in ceaseless revolution, they draw from the parent orb the strength and beauty which clothes their lesser spheres. What wonder, that in vague acknowledgement of his influence, heathen have acknowledged the sun as their God, and worshipped at his shrine. How natural that Christian nations should find in his life-giving power, a fitting emblem of the glory and beneficence of the great Father of the Universe, by whom all suns and systems, are, and were created.



APPENDIX.

IN this Appendix are included formulæ descriptive of chemical reactions, and other matter no less important, whose introduction into the text would have interfered in a measure with the plan of the work.

The formulæ constitute a precise statement, in the language of the symbolical nomenclature, of the reactions already described in more general terms. It is not to be understood from the formulæ that the materials concerned in any process must always be brought together in the precise proportions indicated in the first member of the equation. One or the other may be in excess; if so, the excess is null, and not considered in the formula. The latter regards and indicates only the relative quantities which are actually concerned in each reaction—the first member having reference to the materials employed, and the latter to the products.

Interpreted according to the atomic theory, each formula gives on the one side of the equation, the nature and relative number of the atoms or molecules which take part in any reaction, and on the other, the nature and relative number of those which result.

The student will do well, as an occasional exercise, to calculate from the formulæ the relative quantities of materials required in a reaction, and of products resulting from it in pounds and ounces. $\overline{A}$ $\overline{T}$ in the tables stand respectively for acetic and tartaric acids.

§ 160.

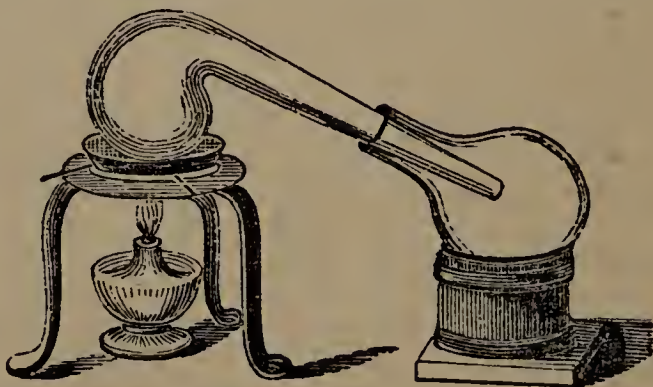
The numbers given in the text are only approximations. The exact quantities may be readily calculated by the law of expansion and contraction of gases and vapors previously given, taking the volume of steam at 212° (§ 193,) as a starting point.

§ 232.

According to the most recent determination, by Regnault, the latent heat of steam is 966.6° . According to the same experimenter the sum of the latent and sensible heat is not rigorously constant.

§ 235.

The apparatus commonly employed in the laboratory for distillation, consists of a retort and receiver, as represented in the figure. In Liebig's apparatus, for the same purpose, the vapors are made to pass from the retort or flask through a long inclined tube. The latter is enclosed in a second tube, which is constantly supplied with cold water. A more perfect condensation is thus effected.



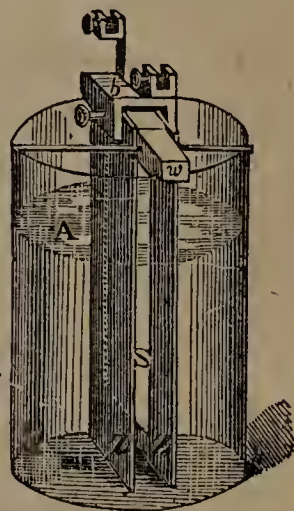
§ 248.

ACTIVE FORCE OF THE GALVANIC CURRENT.—*The active force of the galvanic current, is directly as the whole electromotive force in operation, and inversely as the sum of all the*

impediments to conduction. The above is Ohm's law. By the electro-motive force, is to be understood the whole force generated by the chemical action in the battery. The impediments are found in the imperfect conducting power of the bodies, whether liquid or solid, which enter into the circuit, and the resistance which the current encounters in passing from one to another.

§ 273.

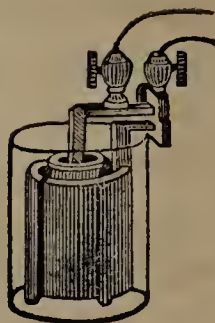
SMEE'S BATTERY.—Of all the batteries in common use, Smee's, which is represented in the figure, is the simplest. It consists of a plate of silver, with plates of zinc hanging near it on either side. The two zinc plates communicate with each other by a metallic connection, and are, therefore, but one plate. It is found best to roughen the silver with platinum black. Smee's batteries are commonly sold in this condition. The clamp and bar are simply to keep the plates in place. Water acidulated with from one-seventh to one-sixteenth of its bulk of oil of vitriol, is employed in this battery. It is generally used in plating.



In explaining the action of sulphuric acid in this battery, it is best to regard it as composed of the radical SO_4 and Hydrogen (p. 449). Substituting $\text{SO}_4 \text{ H}$ for Cl H , the explanation given in paragraph 271 of the text applies to this case also.

GROVES' BATTERY.—In Groves' battery the metal platinum is used instead of copper or silver. It is placed by itself in a porous earthen cup containing nitric acid. The vessel is placed in a larger one containing zinc and sulphuric acid. The two acids mix to some extent through the pores of the inner cup, so as to complete the circuit by their con-

tact. Without this the battery could not operate. No hydrogen is evolved in this battery. Travelling along from the zinc in successive decompositions (271), it comes upon NO_5 , at the point where the two acids meet. H_3 here combines with O_3 of the NO_5 , and the residual NO_2 takes O_3 from the next NO_5 . This action continues till the platinum surface is reached where NO_2 is evolved changing to red fumes of hyponitric acid in the air.



§ 307.

THE ATOMIC THEORY.—That combination takes place in definite and multiple proportions, is directly proved by experiment. Oxygen, for example, unites with hydrogen in the proportion of 8, 16, 32 and 40, to one of the latter element, and refuses to combine in any other proportion. If matter were infinitely divisible, no reason can be assigned for this fact. Each infinitesimal portion of oxygen possessing the same affinities, we should expect to find combination in exact proportion to the quantity supplied.

Dalton's atomic theory, the truth of which is assumed in the text, affords a luminous explanation of the facts under consideration. According to this theory, oxygen combines with hydrogen in no smaller proportion than that of 8 to 1, because this is the ratio of weight in the least existent particles of the two substances. It combines in the proportion of 16, 24, 32 and 40, by uniting 2, 3, 4 or 5 of its atoms to one of Hydrogen. It refuses to combine in any intermediate ratio, because its atoms are indivisible. The same view of the constitution of matter is essential to the explanation of innumerable facts in organic chemistry.

The value of a table of atomic weights does not depend in the least degree upon the reception of the atomic theory. It is a list of combining proportions, determined by careful

analysis, and reduced to a simple standard of comparison. Its truth is independent of all theory.

RELATIONS OF ATOMIC WEIGHT AND DENSITY.—The comparative weight of equal measures or masses of different substances is not necessarily the same as the comparative weight of their atoms. The mass of iron, for example, is heavier, while the atom of iron is lighter than that of potassium. To account for the fact, we must suppose the lighter atoms of iron so closely arranged that they thus more than make up by their larger number, for their inferior weight. In solids generally, there is no correspondence between atomic weight and specific gravity; but in the case of many elements which exist in the gaseous state, or are capable of assuming it, the correspondence is complete, as shown in the following paragraph.

COMBINING MEASURES OR EQUIVALENT VOLUMES.—A cubic foot of nitrogen, weighs just fourteen times as much as the same measure of hydrogen, and the relation of the atomic weight is the same. In combining by atomic weights or equivalents, they therefore combine in equal measures. Chlorine and the vapors of bromine and iodine belong to the same class. Taking hydrogen 1 as the standard, their combining measures are all 1. In the case of oxygen the correspondence referred to does not exist. It is sixteen times as heavy as hydrogen, while its atom weighs but eight times as much; here again we are under the necessity of supposing a closer arrangement of the atoms. Those of oxygen are not only heavier, but twice as closely approximated. Taking hydrogen as the standard, the combining measure of oxygen is therefore $\frac{1}{2}$. That of phosphorus and arsenic is the same, and that of sulphur $\frac{1}{6}$. In the case of most other substances the ratio is not so simple.

In the comparison of combining measures it is more customary to adopt oxygen as the standard of unity. The

combining measure of hydrogen, chlorine, etc., becomes 2, as a consequence, and that of other gases or vapors is proportionally changed. In the production of compound gases, the elements either suffer no condensation or experience a very simple change of volume. Thus hydrochloric acid gas, formed by the combustion of hydrogen and chlorine, possesses the united volumes of its constituents.

EQUIVALENT VOLUMES OF COMPOUND GASES.—As the equivalent or combining proportion of a compound is equal to the sum of the equivalents of its constituents, it follows that the combining measure of hydrochloric acid is equal to the sum of the combining measures of hydrogen and chlorine, $2+2=4$. Ammonia is formed by the union of three volumes of hydrogen and one of nitrogen. Condensation takes place to the amount of $\frac{1}{2}$ of the whole volume of their mixed gases. The combining measure is therefore equal to the sum of the combining measures of the constituents divided by 2. The sum of the combining measures is 8. $8 \div 2 = 4$. Steam is composed of one combining measure (two volumes) of hydrogen, united with one combining measure or volume of oxygen, and condensed to two volumes in combination. Its combining measure is therefore 2. The above instances may serve as examples of the interesting relations of atomic weights, specific quantity and combining measures.

CALCULATION OF SPECIFIC GRAVITY.—The density or specific gravity of a compound vapor or gas of known proportional composition, may be readily calculated from that of its constituents, supposing the amount of condensation which takes place in their combination to be known. The results thus obtained are more accurate than any results of experiment. In like manner the proportional composition of a compound may be calculated from a knowledge of its elements and density. The density of the vapor of carbon and

Other solids which are not known in the gaseous form, may be calculated from the density of their compounds with elementary gases of known density. That of carbon, for example, may be deduced from that of carbonic acid. The calculation involves an assumption as to the equivalent volume of carbon. Assuming it to be the same as that of hydrogen, the density of carbon vapor is 423.4. If its equivalent volume is the same as that of oxygen or $\frac{1}{2}$ that of hydrogen, the density is doubled.

ATOMIC VOLUMES.—It is obvious that the number of atoms of a given weight in any mass, must be in proportion to the density of the mass. The size of the same atoms must be less in the same proportion. The *atomic volume* of any substance is therefore obtained by dividing the atomic weight by the density or specific gravity of the body. The subject of atomic volumes has important relations to the science of crystallography. In comparing atomic volumes it is assumed that the space which a body occupies is completely filled by the atoms, without intervening space.

ATOMIC HEAT.—The numbers 28, 32, 103, represent, in the order in which they are given, the atomic weights of iron, copper, and lead. It is a remarkable fact that if the three metals be taken in these relative proportions, it will require the same expenditure of heat to make them equally hot. 103 pounds of lead can be heated up to 212°, for example, by burning the same amount of alcohol which will heat 32 pounds of copper, or 28 lbs. of iron, to the same degree. Most other metals, and the non-metallic element sulphur, come into the same class, or in other words, have the same atomic heat. The atomic heat of arsenic and silver is double that of the elements above mentioned. Other elements are different in this respect, but commonly by some simple ratio of difference. The correspondence is never absolute, but so close as to have lead

many chemists to attribute the variations to errors of experiment, and to regard the law of correspondence of atomic heat as universal.

§ 313.

CALCULATION OF FORMULÆ.—The student interested in the subject will readily devise for himself the reverse process of calculating formulæ from the per centage results of analysis. The formulæ obtained must obviously be such, that if reconverted into per cents, the numbers obtained will agree very nearly with the results of analysis. There may sometimes be a doubt whether the simplest formula which will express the composition, or some multiple of it is the true one. This can only be decided by the analysis of one of the compounds of the substance in which the formula of the second constituent is established.

The reasoning will be best illustrated by an example. It being assumed that neutral salts contain one equivalent of base to one of acid, the analysis of the neutral sulphate of potassa would establish the formula for sulphuric acid, SO_3 , instead of S_2O_6 . KO,SO_3 would express correctly the composition of the salt, while the substitution of S_2O_6 for S O_3 in the same formula, would give a double proportion of acid.

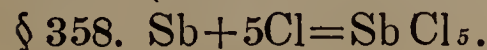
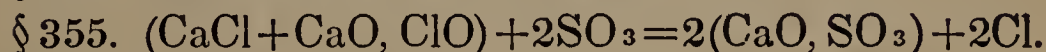
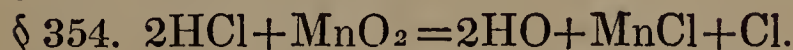
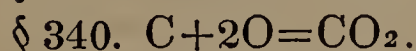
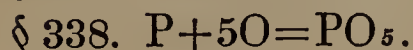
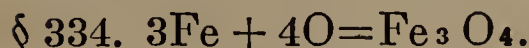
§ 323.

When the same element unites with oxygen in different proportions to form different acids, these are distinguished by prefixes and terminations which indicate the order in which they stand to each other with respect to the quantity of oxygen.

The first acid of such a series discovered, generally receives the termination "ic." Chloric acid may serve as an example. Another acid compound of chlorine since discovered,

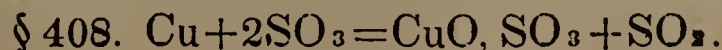
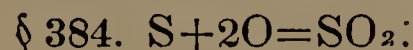
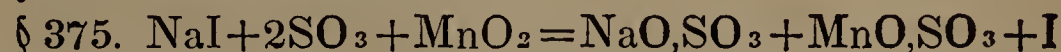
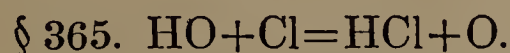
and containing more oxygen, is called hyperchloric, signifying higher than chloric. The other names of the list indicate, by their prefixes and terminations, the order of oxygenation of the several acids. The same means of distinction are employed in other series.

Hypochlorous acid,	-	-	-	-	ClO.
Chlorous acid,	-	-	-	-	ClO ₂ .
Hypochloric acid, (peroxide of chlorine,)					ClO ₄ .
Chloric acid,	-	-	-	-	ClO ₅ .
Hyperchloric acid,	-	-	-	-	ClO ₇ .



§ 362.

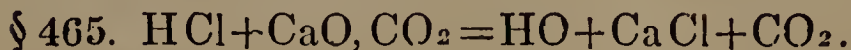
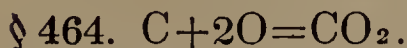
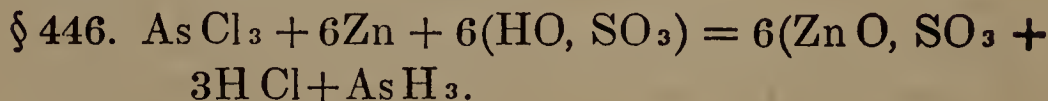
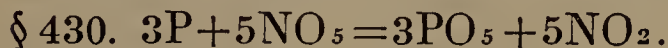
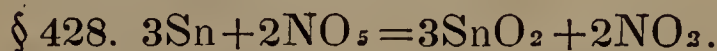
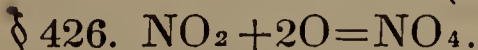
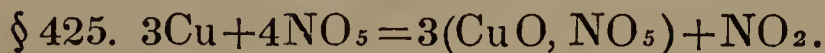
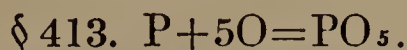
It will be observed, on comparing § 362 with those which precede, that chlorine sometimes expels oxygen, and is sometimes expelled by it. In relation to the apparent inconsistency of these facts, little more can be said than that chemical affinities are modified by circumstances, the action of which is not perfectly understood.

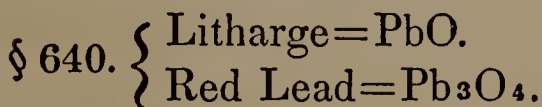
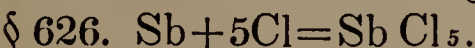
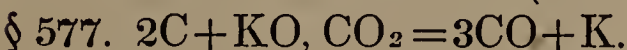
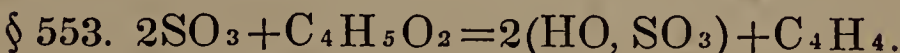
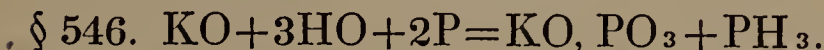
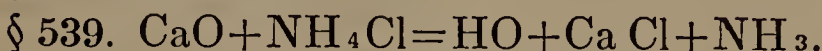
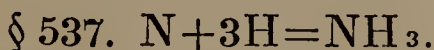
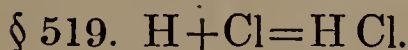
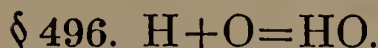
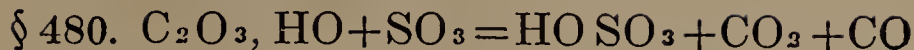
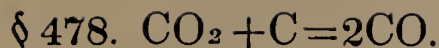


§ 411.

IODIDE OF NITROGEN.—Iodide of Nitrogen, a very explosive compound, is formed when an alcoholic solution of iodine is added to *aqua ammoniacæ*. It precipitates in the form of a black powder. The precipitate should be thrown upon a filter, washed, and while still moist, divided into small portions for the purpose of experiment. When dry it explodes violently by simple touch, and sometimes even spontaneously.

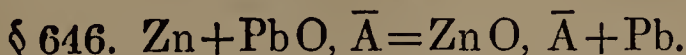
CHLORIDE OF NITROGEN.—Chloride of nitrogen is a still more dangerous compound than the above. To prepare it a jar filled with chlorine gas is suspended over a solution of sal ammoniac, contained in a leaden saucer. After the lapse of a few hours, an oily liquid forms and falls to the bottom of the solution. This is the chloride of nitrogen. Mere contact with a combustible material, such as fat, oil, phosphorus, &c., is sufficient to cause its explosion. A single drop of the liquid explodes so violently as to shatter to pieces any earthen or glass vessel upon which the explosion takes place. The preparation of this compound cannot be recommended; in the hands of the ablest experimenters it has been the occasion of the most dangerous accidents.





§ 680.

The other elements not mentioned in the text are glucinum, cadmium, cerium, columbium or tantalum, didymium, erbium, iridium, lanthanum, molybdenum, niobium, norium, osmium, palladium, pelopium, rhodinm, ruthenium, selenium, tellurium, terbium, thorium, titanium, tungsten or wolframium, vanadium, yttrium and zirconium. With the exception of selenium and tellurium, which are analogous in their properties to sulphur, they may be classed with the metals. They are of rare occurrence, and may be regarded as sustaining the same relation to the other elements as do the asteroids and satellites to the more important members of the solar system.



§ 685.

NEUTRAL, ACID, AND BASIC SALTS.—In general, salts containing an equivalent of base to an equivalent of acid are called neutral. The composition fixes the name, whether exactly neutral to the taste and in their action on vegetable colors, or not. Salts containing more acid in proportion are called super-salts or acid salts, and those containing more base, sub-salts or basic salts.

There are two exceptions to the above rules. The first is that of certain classes of acids which have double and treble neutralizing power, and require, therefore, the first two atoms, and the latter three atoms of base, to make them neutral salts. Such acids are bibasic and tribasic, in contradistinction from the mono-basic or ordinary acids. Phosphoric acid is one of the latter class of tribasic acids, and the neutral phosphates have therefore three atoms of base and is called a tribasic phosphate. Phosphates containing more acid or base than their proportion, are acid or basic accordingly.

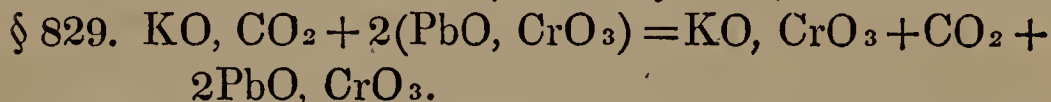
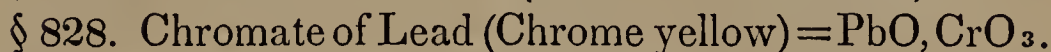
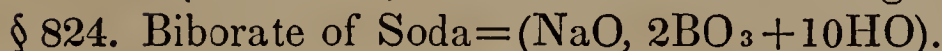
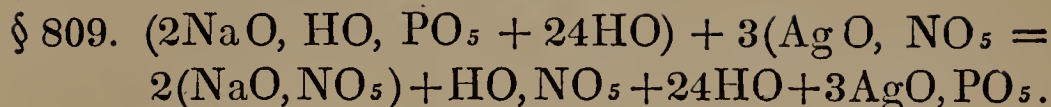
The second exception is that of salts or bases which contain more than one atom of oxygen to an atom of metal. In proportion as they contain more, they neutralize more acid. Alumina or oxide of aluminium, for example, contains three atoms of oxygen. Its neutral sulphate, therefore, is a salt containing 3 atoms of acid. A salt of aluminium containing more or less than their proportion, is acid or basic accordingly.

DOUBLE SALTS.—There are also double salts or compounds of salts with each other. They are generally of the same acid. Thus alum is a double sulphate of potassa and alumina and the bisulphate of potassa may be regarded as a double sulphate of potassa and water. Such double salts

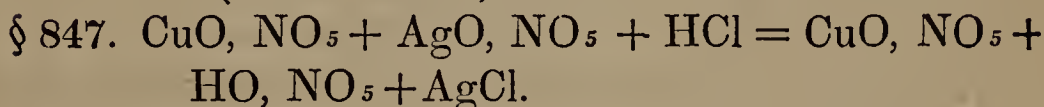
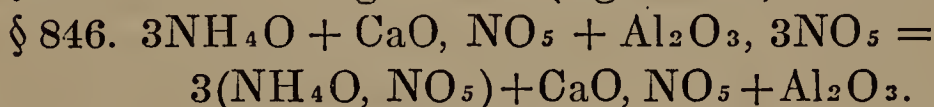
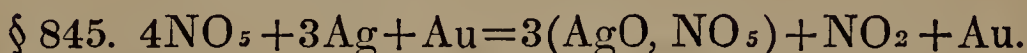
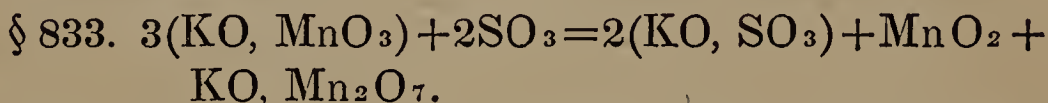
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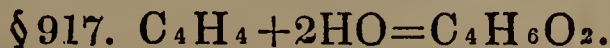
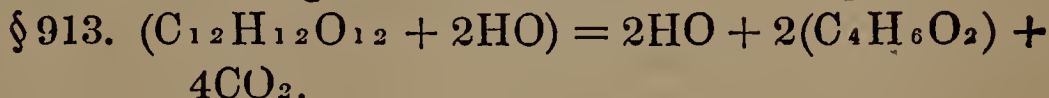
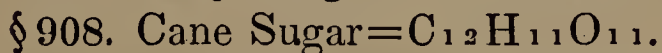
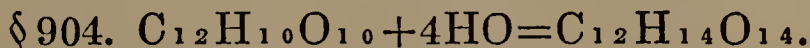
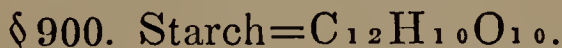
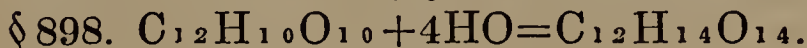
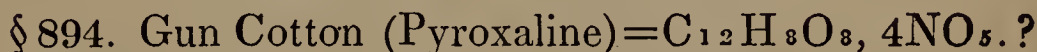
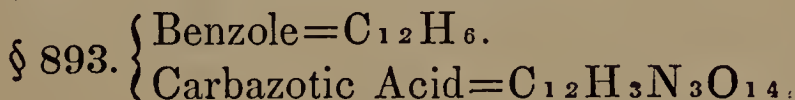
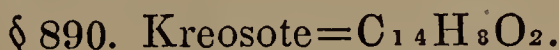
CO₂,



§ 830. Commercial chrome green is a mixture of Prussian blue and chrome yellow.



§ 871. During the night a reverse process of absorption of oxygen and exhalation of carbonic acid takes place, to a small extent.



§ 919.

FULMINATES.—This name has been given to a class of highly explosive salts, obtained by the action of alcohol upon certain nitrates. The most important are the fulminates of mercury and silver. Fulminating mercury is prepared by dissolving 1 part of mercury in 12 parts of nitric acid, sp. grav. 1.36, and subsequently adding 11 parts of 80 per cent. alcohol. Upon warming the mixture a complicated reaction takes place, dense white vapors are given off, and the fulminate is thrown down as a crystalline powder. This is to be washed with cold water and afterwards dried at a moderate temperature. This salt explodes violently by heat, friction, or percussion, and sometimes even without any apparent cause. It is largely employed in the manufacture of percussion caps, torpedoes, &c., &c. Fulminating silver detonates still more violently than the mercury salt. By friction with a hard body, it explodes even under water. It is prepared as above, using 10 parts of nitric acid and 20 parts of alcohol. Too much caution cannot be observed in manipulating with these highly dangerous compounds. They should be prepared only in quantities of a few grains. Fulminate of Silver= 2AgO , Cy_2O_2 .

§ 927. Ether= $\text{C}_4\text{H}_5\text{O}$.

§ 928. $\left\{ \begin{array}{l} \text{Alcohol}=\text{C}_4\text{H}_6\text{O}_2 \text{ or } (\text{C}_4\text{H}_5\text{O}+\text{HO}). \\ (\text{C}_4\text{H}_5\text{O}+\text{HO})+\text{SO}_3=\text{HO}, \text{SO}_3+\text{C}_4\text{H}_5\text{O}. \end{array} \right.$

§ 929. $\text{C}_4\text{H}_5\text{I}+\text{Zn}=\text{ZnI}+\text{C}_4\text{H}_5$.

§ 930. $\text{C}_4\text{H}_6\text{O}_2+2\text{SO}_3=2(\text{HO}, \text{SO}_3)+\text{C}_4\text{H}_4$.

§ 931. $\text{C}_4\text{H}_6\text{O}_2+2\text{O}=2\text{HO}+\text{C}_4\text{H}_4\text{O}_2$.

§ 932. Aldehyde= $\text{C}_4\text{H}_4\text{O}_2$.

§ 933. $\text{C}_4\text{H}_4\text{O}_2+2\text{O}=\text{C}_4\text{H}_4\text{O}_4$.

§ 935. Chloroform= C_2HCl_3 .

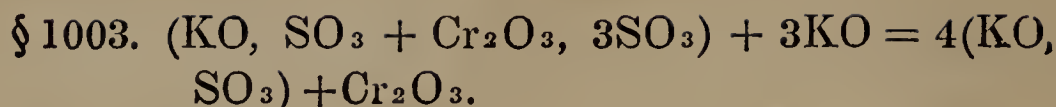
§ 938. Tannic Acid= $\text{C}_{18}\text{H}_5\text{O}_9$, $3\text{HO}=\text{Qt}$, 3HO .

- § 941. Cyanogen = $C_2N = Cy$. An arbitrary symbol.
- § 942. $FeCy, 2KCy + HgCl_2 = FeCy, 2KCl + Hg + 2Cy$.
- § 943. Cyanide of Potassium = $KC_2N = KCy$.
- § 944. Prussian Blue = $C_{18}N_9Fe_7 = Fe_4Cfy_3$.
- § 945. { Ferrocyanogen = $3Cy, Fe = Cfy$.
 Ferrocyanide of Potassium = $(3Cy, Fe + 2K) = Cfy, 2K$.
- § 946. $2(3Cy, Fe + 2K) - K = (2(3Cy, Fe) + 3K) = 2Cfy, 3K$.
- § 947. $KCy + HO, SO_3 = KO, SO_3 + HCy$.
- § 949. { Tartaric Acid = $C_8H_4O_{10}, 2HO = \bar{T}, 2HO$.
 Oxalic Acid = $C_2O_3, HO = \bar{O}, HO$.
 Citric Acid = $C_{12}H_5O_{11}, 3HO = \bar{C}i, 3HO$.
 Malic Acid = $C_8H_4O_8, 2HO = \bar{M}, 2HO$.
 Formic Acid = C_2HO_3, HO .
 Lactic Acid = $C_6H_5O_5, HO$.

§ 975.

In the present state of our knowledge in respect to the protein bodies, we must abandon every formula designed to express their atomic constitution. They contain in a hundred parts: 55.16 carbon, 7.05 hydrogen, 21.81 oxygen, 16.96 nitrogen, with $\frac{1}{2}$ to 1 per cent. sulphur and phosphorus in an unknown form.

- § 991. { Morphine = $C_{35}H_{20}NO_6$.
 Strychnine = $C_{44}H_{23}N_2O_8$ or $C_{44}H_{24}N_2O_8$.
 Quinine = $C_{26}H_{12}NO_2$.
 Theine and Caffeine = $C_{19}H_{10}N_4O_4$.
- § 993. Indigo = $C_{16}H_5NO_2$.
- § 994. Alizarine = $C_{20}H_{10}O_{10}$.
- § 995. Hematoxyline = $C_{40}H_{17}O_{15}$.
- § 1002. *Vide* § 994.



§ 1025.

MODE OF ESTIMATING THE VALUE OF GUANO, &c.—In estimating the money value of guano for agricultural purposes, ammonia may be set down at 16 cents per pound, potash at 4 cents, and phosphoric acid at $1\frac{1}{2}$ to 2 cents. As far as the latter exists in a soluble form, its value is doubled. Other substances are of so little comparative value that they need not be taken into the account. These valuations are based, not alone on their relative value as fertilizers, but on the cost of the different substances when obtained from other sources. They are somewhat arbitrary, but may serve as a means of approximate estimation of the value of guano and other fertilizers.

As an average of the composition of thirteen samples of Peruvian guano, Prof. Way obtained the following results : ammonia, 17.41 per cent. ; phosphoric acid, 11.13 ; potash, 3.50. This would seem to be considerably above the ordinary average. The pecuniary value of such an article, according to the above valuation, would be \$63.00 per ton, of which \$55.60 would lie in the ammonia. No distinction is made in the potential and actual ammonia of guano, because the conversion of the former into actual ammonia takes place so rapidly in the soil. But the potential ammonia of most nitrogenous substances, as of clippings of hides and other similar refuse, is to be estimated at least 25 per cent. lower, in view of their comparatively slow conversion.

In all analyses of concentrated fertilizers excepting guano, in which the first distinction may be neglected, the amount of actual and potential ammonia, of soluble and insoluble phosphoric acid, and of potassa, should be separately stated.

The latter constituent is, however, of comparatively little importance. The farmer who purchases his artificial fertilizers without a skillful and well attested analysis, is at the mercy of the ignorant or unscrupulous dealer.

§ 1046. Glycerine = $C_3H_8O_3$.

§ 1047. $\left\{ \begin{array}{l} \text{Stearic Acid} = C_{68}H_{66}O_6, 2HO = \bar{S}t, 2HO. \\ \text{Margaric Acid} = C_{34}H_{33}O_3, HO. \\ \text{Oleic Acid} = C_{36}H_{33}O_3, HO. \end{array} \right.$

§ 1060. $\left\{ \begin{array}{l} \text{Urea} = C_2N_2H_4O_2. \\ \text{Uric Acid} = C_{10}N_4H_3O_5 + HO. \end{array} \right.$

§ 1061. The view long entertained of the production of urea in the blood by the oxidation of the effete tissues has recently been confirmed by the artificial production of this substance from gluten, albumen and fibrine by a process of oxidation.

TABLE I

TABLE OF THE DISCOVERY OF CERTAIN ELEMENTS.

Names of Elements.	Authors of the discovery.	Dates.
Gold, . . .	Known to the ancients.	
Silver, . .		
Iron, . . .		
Copper, . .		
Mercury, . .		
Lead, . . .		
Tin, ...		
Sulphur, . .		
Carbon, . .		
Antimony, . . .	Described by Basil Valentine, ...	1490
Bismuth, . . .	Described by Agricola, ...	1530
Zinc, ...	First noted by Paracelsus, ...	16th century.
Phosphorus, . .	Brand, ...	1660
Arsenic, . . .	Brant, ...	1733
Cobalt, . . .		
Hydrogen, . .	Cavandish, ...	1766
Chlorine, . . .	Scheele, ...	1774
Oxygen, . . .	Priestly, ...	1774
Manganese, . .	Gahn and Scheele, ...	1774
Chromium, . .	Vauquelin, ...	1797
Potassium, . .	Sir Humphrey Davy, ...	1807
Sodium, . . .		
Barium, . . .		
Strontium, . .		
Calcium, . . .		
Boron, ...		
Iodine, ...	Courtois, ...	1811
Silicon, ...	Berzelius, ...	1823
Bromine, . . .	Ballard, ...	1826
Aluminium, . .	Wohler, ...	1828
Magnesium, . .	Bussy, ...	1829

TABLE II.

ATOMIC WEIGHTS.*

Hydrogen=1.00.

Aluminium	Al	13.63	Lead	Pb	103.57
Antimony	Sb	129.00	Lithium	Li	6.64
Arsenic	As	75.00	Magnesium	Mg	12.00
Barium	Ba	68.59	Manganese	Mn	27.57
Bismuth	Bi	208.00	Mercury	Hg	100.05
Boron	B	11.04	Nickel	Ni	29.55
Bromine	Br	79.97	Nitrogen	N	14.00
Calcium	Ca	20.00	Oxygen	O	8.00
Carbon	C	6.00	Phosphorus	P	31.36
Chlorine	Cl	35.46	Platinum	Pt	98.94
Chromium	Cr	26.78	Potassium	K	39.11
Cobalt	Co	29.49	Silicon	Si	14.81
Copper	Cu	31.68	Silver	Ag	107.97
Fluorine	Fl	19.00	Sodium	Na	23.00
Gold	Au	196.67	Strontium	Sr	43.67
Hydrogen	H	1.00	Sulphur	S	16.00
Iodine	I	126.88	Tin	Sn	58.82
Iron	Fe	28.00	Zinc	Zn	32.53

* These atomic weights are calculated from the best and most precise investigations; some of them have not yet been established by recent experiment, but are calculated from ~~values~~ so determined.

FRESERIUS.

TABLE III.
SPECIFIC GRAVITY OF SOLIDS.
Pure water at 60° F=1.000

Platinum	20.98	Tin	7.29
Gold, ...	19.26	Zinc	7.03
Mercury	13.60	Antimony	6.70
Lead	11.45	Sulphur	1.98
Silver	10.50	Chromuim	6.00
Bismuth	9.80	Arsenic	5.80
Copper	8.87	Iodine	4.95
Cobalt.	8.54	Aluminium	2.60
Nickel	8.28	Phosphorus	1.86
Manganese	8.00	Sodium	0.97
Iron	7.80	Potassium	0.86

TABLE IV.
SPECIFIC GRAVITY OF LIQUIDS.
Pure water at 60° F=1.000

Mercury	13.596	Ammonia	0.870
Bromine	2.79 to 3.19	Turpentine	0.865
Sulphuric Acid.	1.800	Alcohol	0.800
Nitric Acid	1.515	Ether	0.720

TABLE V.
SPECIFIC GRAVITY OF GASES.
Dry air at 60° F=1.000

Chlorine	2.454	Oxygen	1.109
Nitrous Oxide	1.525	Carbonic Oxide	0.970
Carbonic Acid	1.525	Nitrogen	0.970
Fluorine	1.296	Hydrogen	0.069
Hydrochloric Ac. gas . . .	1.261	Ammoniacal gas	0.589

TABLE VI.

LINEAR EXPANSION OF SOLIDS ON BEING HEATED FROM 32° TO 212° F.

Zinc (cast)	<i>expands</i>	$\frac{1}{323}$	Iron	<i>expands</i>	$\frac{1}{182}$
Zinc (sheet)	"	$\frac{1}{340}$	Steel (tempered)	"	$\frac{1}{812}$
Lead	"	$\frac{1}{351}$	Steel (untempered)	"	$\frac{1}{927}$
Silver	"	$\frac{1}{524}$	Platinum	"	$\frac{1}{1167}$
Copper	"	$\frac{1}{581}$	Flint Glass	"	$\frac{1}{1248}$
Gold	"	$\frac{1}{682}$	Black Marble	"	$\frac{1}{2833}$

TABLE VII.

SPECIFIC HEAT.

Water=1.000

Alcohol	0.660	Phosphorus	0.187
Ether	0.520	Iron	0.113
Nitric Acid	0.442	Zinc	0.099
Oil of Turpentine	0.425	Arsenic	0.081
Sulphuric Acid	0.333	Tin	0.056
Carbon	0.241	Iodine	0.054
Common Salt	0.225	Silver	0.050
Lime	0.205	Mercury	0.033
Sulphur	0.202	Platinum	0.032
Glass	0.197	Gold	0.032

TABLE VIII.

MELTING POINTS OF SOLIDS.

Cast Iron	<i>melts at</i>	3479°	Potassium	<i>melts at</i>	154°
Cobalt	" "	2800°	Wax	" "	142°
Silver	" "	2283°	Spermaceti	" "	112°
Gold	" "	2016°	Phosphorus	" "	108°
Copper	" "	1996°	Tallow	" "	92°
Lead	" "	612°	Olive Oil	" "	36°
Bismuth	" "	497°	Ice	" "	32°
Tin	" "	442°	Oil of Turpentine	" "	—14°
Sulphur	" "	226°	Mercury	" "	—39°
Newton's Alloy	" "	208°	Liquid Ammonia,	" "	—40°
Sodium	" "	194°	Ether	" "	—47°

TABLE IX.

BOILING POINTS OF LIQUIDS.

Mercury	<i>boils at</i>	662°	Nitric Acid	<i>boils at</i>	248°
Whale Oil	" "	630°	Water	" "	212°
Sulphuric Acid	" "	620°	Alcohol	" "	173°
Sulphur	" "	600°	Bromine	" "	116°
Phosphorus	" "	551°	Ether	" "	96°
Oil of Turpentine	" "	312°	Sulphurous Acid	" "	14°

TABLE X.

COMPOSITION OF HUMAN BLOOD ACCORDING TO LECANU.

Water	78.015
Fibrin	0.210
Albumen	6.509
Blood-globules, ...	13.300
Crystallizable fat	0.243
Oily fat	0.131
Salts of the alkilies	0.837
Salts of earths and ox. of iron	0.210
Other substances	0.545
	100.000

TABLE XI.

COMPOSITION OF COW'S MILK.

Water	873.0
Casein, and a little albumen	48.2
Butter	30.0
Sugar of milk	43.9
Phosphate of lime with a little chloride of calcium	2.3
Phosphate of iron and magnesia, and a little soda	0.9
Chlorides of sodium and potassium	1.7
	1000.00

TABLE XII.

RELATIVE PROPORTIONS OF THE SANGUIGENOUS TO THE RESPIRATORY CONSTITUENTS IN DIFFERENT KINDS OF FOOD.

	<i>Sanguigenous.</i>	<i>Respiratory.</i>	
Cow's milk	contains, for 10	30=	{ 8.8 fat and 10.4 milk sugar
Human milk	" 10	40	
Horse beans	" 10	22	
Peas	" 10	23	
Fat mutton	" 10	27=	11.25 fat
Fat pork	" 10	30=	12.5 "
Beef	" 10	17=	7.08 "
Veal	" 10	1=	0.41 "
Wheat flour	" 10	46	
Oatmeal	" 10	50	
Rye flour	" 10	57	
Barley	" 10	57	
Potatoes (white)	" 10	86	
Potatoes (blue)	" 10	115	
Rice	" 10	123	
Buckwheat	" 10	130	

Starch is the principal constituent of respiratory food in the substances mentioned in the table. When sugar and fat take its place, the fact is separately indicated, while their equivalent in starch is given in the principal column for convenience of comparison. The above table is taken from Liebig's Letters on Chemistry.

TABLE XIII.

PER CENT BY MEASURE OF ALCOHOL IN SPIRITOUS LIQUORS AT 62° F.

Rum	contains	72 to 77	per cent.
Cognac	"	50 " 54	"
Whiskey	"	59	"
Geneva	"	50	"
Port	wine	21 to 23	"
Sherry	"	15 " 25	"
Madeira	"	18 " 22	"
Malmsey	"	16	"
Claret	"	9 to 15	"
Burgundy	"	7 " 13	"
Rhenish	"	8 " 13	"
Moselle	"	8 " 9	"
Tokay	"	9	"
Champagne	"	5 to 15	"

TABLE XIV.

SOLUBILITY OF SUBSTANCES

	KO	NaO	NH ₄ O	BaO	SrO	CaO	MgO	Al ₂ O ₃	MnO	FeO	NiO
	1	1	1	1	1	1 2	2	2	2	2	2
S	1	1	1	1	1	1 2	2		2	2	
Cl	1	1	1	1	1	1	1	1	1	1	1
I	1	1	1	1	1	1	1		1	1	
SO ₃	1	1	1	3	3	1 2	1	1	1	1	1
NO ₅	1	1	1	1	1	1	1	1	1	1	1
PO ₅	1	1	1	2	2	2	2		2	2	2
CO ₂	1	1	1	2	2	2	2		2	2	2
C ₂ O ₃	1	1	1	2	2	2	2	2	2	1 2	
BO ₃	1	1	1	2	2	2	2	2	2	2	2
$\overline{A}$	1	1	1	1	1	1		1	1	1	1
$\overline{T}$	1	1	1	2	2	2	1 2	1	1 2	1 2	
AsO ₅	1	1	1	2	2	2	2	2	2	2	2
AsO ₃	1	1	1	2	2	2				2	2
CrO ₃	1	1	1	2	2	2	1	2	1		2

EXPLANATION OF THE TABLE.

To ascertain the solubility or insolubility of a salt from the above table, its acid is sought in the left hand column, and its base in the upper line. The square, which is in line

TABLE XIV.—(CONTINUED.)

IN WATER AND ACIDS.

	ZnO	PbO	SnO	SnO ₂	BiO ₃	CuO	Hg ₂ O	HgO	AgO	PtO ₂	SbO ₃
	2	2	2	2 3	2	2	2	2	2		2
S	2	2			2		3	3			2
Cl	1	1 2	1	1	1	1	2	1	3		1
I	1	2	2	1			2	2	3		
SO ₃	1	2	1		1	1	1 2	1	1 2	1	2
NO ₅	1	1			1	1	1	1	1	1	
PO ₅	2	2				2	2	2	2		
CO ₂	2	2			2	2	2	2	2		
C ₂ O ₃	2	2	2	1	2	2	2	2	2		1 2
BO ₃	2	2	2		2	2	1				
$\overline{A}$	1	1	1	1	1	1	1 2	1	1		1
$\overline{T}$	2	2	1 2		2	1	1 2	2	2		1
AsO ₅		2			2	2	2	2	2		2
AsO ₃		2				2	2	2	2		2
CrO ₃	1	2	2		2	2	2	1 2	2		2

with both, contains the desired information. The numeral 1, indicates solubility in water; 2, solubility in either nitric or hydrochloric acid, and 3, insolubility in either. The smaller numerals indicate a low degree of solubility.

TABLE XV.

HOMOLOGOUS SERIES OF ORGANIC ACIDS.

1. Formic	$C_2H_2O_4$	16. Ethalic	$C_{32}H_{32}O_4$
2. Acetic	$C_4H_4O_4$	17. Stearic	$C_{34}H_{34}O_4$
3. Propionic	$C_6H_6O_4$	18. Bassic	$C_{36}H_{36}O_4$
4. Butyric	$C_7H_8O_4$	19.	
5. Valeric	$C_{10}H_{10}O_4$	20.	
6. Caproic	$C_{12}H_{12}O_4$	21.	
7. Enanthylic	$C_{14}H_{14}O_4$	22. Behenic	$C_{44}H_{44}O_4$
8. Caprylic	$C_{16}H_{16}O_4$	23.	
9. Pelargonic	$C_{18}H_{18}O_4$	24.	
10. Capric	$C_{20}H_{20}O_4$	25.	
11. Margaritic	$C_{22}H_{22}O_4$	26.	
12. Lauric	$C_{24}H_{24}O_4$	27. Cerotic	$C_{54}H_{54}O_4$
13. Cocinic	$C_{26}H_{26}O_4$	28.	
14. Myristic	$C_{28}H_{28}O_4$	29.	
15. Benic	$C_{30}H_{30}O_4$	30. Melissic	$C_{60}H_{60}O_4$

TABLE XVI.

COMPOSITION OF THE ASHES OF COMMON CROPS.

	Indian Corn.	Wheat	Wheat Straw.	Rye.	Oats.	Pota- toes.	Tur- nips.	Hay.
Carbonic acid,	trace.					10.4		
Sulphuric acid,	0.5	1.0	1.0	1.5	10.5	7.1	13.6	2.7
Phosphoric acid,	49.2	47.0	3.1	47.3	43.8	11.3	7.6	6.0
Chlorine, . . .	0.3	trace.	0.6		0.3	2.7	3.5	2.6
Lime, ...	0.1	2.9	8.5	2.9	4.9	1.8	13.6	22.9
Magnesia, . . .	17.5	15.9	5.0	10.1	9.9	5.4	5.3	5.7
Potash, ...	23.2	29.5	7.2	32.8	} 27.2	51.5	42.0	18.2
Soda, ...	3.8	trace.	0.3	4.4		trace.	5.2	2.3
Silica, ...	0.8	1.3	67.6	0.2	2.7	8.6	7.9	37.9
Iron, ...	0.1	trace.	1.0	0.8	0.4	0.5	1.3	1.7
Charcoal in ash, } and loss, . }	4.5	2.4	5.7		0.3	0.7		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lbs. of material } requir'd to yield } 100 lbs. of ashes. }	10000	5000	2000	5000	2500	6000 to 13000	12500 to 20000	1000 to 2000

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- $\frac{1}{2}$ oz. Tartar Emetic.
 - $\frac{1}{4}$ " Iodide of Potassium.
 - $\frac{1}{4}$ " Iodine.
 - $\frac{1}{8}$ " Potassium.
 - $\frac{1}{8}$ " Solution of Chloride of Platinum.
 - 1 Glass, (4 oz.) Spirit Lamp.
 - Fine platinum foil and wire.
 - 1 doz. assorted test-tubes.
 - $\frac{1}{2}$ sheet blue Litmus Paper.
 - $\frac{1}{2}$ " red Litmus Paper.
 - Fine Iron Wire.
 - * Sheet Zinc.
 - * Sheet Copper.
 - * Sulphuric Acid, (Oil of Vitriol.)
 - * Hydrochloric Acid, (Muriatic Acid.)
 - * Nitric Acid, (*aqua fortis*.)
 - * Alcohol.
 - * Ether
 - * Clay Pipes and Vials.
 - * Bowls, Tumblers, &c.
-

* Not contained in the box of apparatus and materials put up to accompany this work.

LIST OF CHEMICALS AND APPARATUS REQUIRED FOR THE EXPERIMENTS DESCRIBED IN THIS WORK.

- 1 lb. Black Oxide of Manganese
- $\frac{1}{4}$ " Bleaching Powders.
- $\frac{1}{4}$ " Chlorate of Potassa.
- $\frac{1}{4}$ " Alum.
- $\frac{1}{4}$ " Sulphur.
- $\frac{1}{4}$ " Common Caustic Potash, in Sticks.
- $\frac{1}{4}$ " Acetate of Lead, (Sugar of Lead.)
- $\frac{1}{4}$ " Sulphate of Copper, (Blue Vitriol.)
- $\frac{1}{4}$ " Carbonate of Ammonia, (Sal Volatile.)
- 2 oz. Bichromate of Potash.
- 2 " Bone Black.
- 2 " Sulphuret of Iron.
- 2 " Nitrate of Potash, (Salt Petre.)
- 1 " Chloride of Ammonium, (Sal Ammoniac.)
- 1 " Yellow Prussiate of Potash.
- 1 " Cyanide of Potassium.
- 1 " Oxalic Acid.
- 1 " Ground Nut Galls.
- 1 " Phosphorus.
- 1 " Fluor Spar.
- 1 " Borax.
- 1 " Chloride of Barium.
- 1 " Chloride of Strontium.
- 1 " Chloride of Mercury, (Corrosive Sublimate.)
- 1 " Beeswax.
- 1 " Metallic Antimony
- 1 " Block Tin.
- 1 " Bismuth.
- 2 " Mercury, (Quicksilver.)
- 1 " Arsenious Acid, (Ratsbane.)

